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Monterey, California

THESIS

QUANTITATIVE ASSESSMENT OF THIRD WORLD

SEA DENIAL CAPABILITIES

by

Lowell Edwin Jacoby

March 1977

Thesis Advisor: E. J. Laurance

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QUANTITATIVE ASSESSMENT OF THIRD WORLD SEA DENIAL CAPABILITIES

by

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Submitted in partial fulfillment of the
requirements for the degree of

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I. INTRODUCTION

"The qualitative transformations which have taken place in naval forces have also changed the approach to evaluating the relative might of navies and their combat groupings: we have had to cease comparing the number of warships of one type or another and their total displacement (or the number of guns in a salvo or the weight of this salvo), and turn to a more complex, but also more correct appraisal of the striking and defensive power of ships, based on a mathematical analysis of their capabilities and qualitative characteristics."

Admiral Sergei G. Gorshkov
Commander-in-Chief of the Soviet Navy
"Navies in War and Peace"
(*Morshkoy Sbornik*, No. 2, 1972)

Transfers of sophisticated weapons systems to Third World nations have generated increasing concern within the United States in recent years. One need only follow the public debates over proposed sales of various weapons to note the level of interest. For example, within the past year there have been heated discussions centering around the proposed transfer of PERSHING surface-to-surface missiles to Israel, the sale of advanced fighters (F-14, F-15, F-16) to Iran and Israel, the intent to deliver HAWK surface-to-surface missiles to Jordan and the Saudi Arabian request for SIDEWINDER air-to-air missiles.

Interest in the growth of Third World naval capabilities has tended to lag behind anxiety created by transfers of air- and ground-related systems. However, world attention was directed to lesser developed nations' naval capabilities by several dramatic events which occurred during the 1967-1973 timeframe. Antiship missiles destroyed the USS Liberty and the Israeli destroyer "Eilat" in 1967. A Pakistani DAPHNE SS sank the Indian destroyer "Khurkri" in 1970. The Israelis utilized GABRIEL surface-to-surface missiles (SSMs) and SAAR PTFGs to decimate Egyptian and Syrian missile boat forces in October 1973.

These attacks brought the naval threat to public notice. The implications for military planners and Western policymakers became clear--Third World antiship missile combatants and torpedo-firing submarines present a threat to ships of maritime powers. Since the threat is credible, Third World recipients of these systems have the ability to influence the actions of world powers and to utilize naval forces as foreign policy tools. Further, Third World nations, acting singly or in concert, have the means to deny limited ocean areas to Western navies. Some of these ocean areas, such as the Persian Gulf and the Straits of Malacca, are vital to Western military and economic interests.

The following crisis scenario emphasizes the nature and extent of this threat. It is set in the approximate political circumstances of 1977 to present a plausible framework for focusing attention on the naval capabilities of the participants. The naval inventories upon which the scenario is based are real. The concerns of analysts tasked with evaluating Third World naval forces are also genuine.

A. SCENARIO

On 25 March 1980 Iraq invaded Kuwait. Iraq justified the invasion on the grounds of long-standing claims to border areas between the two nations. Western observers view the attack as an attempt to capture Kuwaiti oil reserves in light of the rapid depletion of Iraqi petroleum supplies. Kuwait's Western-equipped army blunted the initial thrust, but the smaller Kuwaiti force will be defeated without massive resupply from the West and/or outside military assistance.

Fears that an Iraqi victory might presage a similar attack on Saudi oil-producing areas prompted Saudi Arabia to order its military forces into Kuwait on 27 March. Both

countries immediately called on the United States for military resupply. As of 31 March, the United States has not responded. Aerial resupply of Kuwait is infeasible. The United States is hesitant to commit merchant ships and/or its small Indian Ocean naval force to the restricted waters of the Persian Gulf given the existing antiship missile threat. Alternative options, such as a naval resupply through Saudi Red Sea ports, probably would not permit delivery of urgently needed military equipment in time to prevent Kuwait's defeat.

The Saudi decision to assist Kuwait raised concern in Iraq that the modern Saudi Navy might be able to secure the Persian Gulf sea lanes and allow supplies to reach Kuwait by sea in time to affect the military outcome. Thus, on 28 March Iraq requested naval support from Iran. The Iranian Navy is recognized as the dominant naval force in the Persian Gulf. The Shah of Iran demanded that Iraq relinquish all claims to offshore oil-producing areas in dispute between the two nations in return for his support. Two days later Iraq accepted his condition and the Shah instituted a naval blockade of the Persian Gulf. Little oil has flowed from the Gulf since hostilities began on the 25th. Western shipowners felt that the risk of attack by

Iraqi OSA PTFGs was too high to allow tankers to enter the Gulf. With the institution of the Iranian blackade all oil shipments from the area ceased. As a result, severe petroleum shortages are anticipated in Western Europe and Japan.

Libyan President Qadhaafi saw the crisis as an opportunity to strike back at his moderate Arab foes. On 28 March he declared a "combat zone" extending 50 miles off the Egyptian coast and threatened to sink any shipping operating within this area. The action effectively blocked the Suez Canal and halted Saudi oil shipments to Europe from pipeline terminals on the Egyptian coast. The Libyan decision carried the tacit approval of the Soviet Union, Libya's major arms supplier.

On the following day a British tanker and a Japanese merchant ship were sunk by submarines off Alexandria, Egypt. Later that same day, a U.S. merchant ship was attacked by an unidentified submarine off the Israeli coast. The submarines involved are believed to be FOXTROT SSs delivered to Libya by the Soviet Union between 1977 and 1979. However, some analysts suggest that the attacks could have been conducted by Soviet FOXTROTs which typically operate in

the Mediterranean. These observers emphasize the minimal risk attached to such action because of the inability to differentiate between a submerged Libyan FOXTROT and a Soviet submarine of the same class. At the same time, the Soviets could derive substantial gains from an emphatic show of support for their radical Arab clients.

On 29 March Egypt called upon Western naval powers to assist in breaking the Libyan blockade. No decision has been announced to date. The United States is reluctant to commit less than a major air and sea effort to the task given the 30-40 Libyan missile boats and unknown number of submarines believed to be operating in the area. On the afternoon of the 29th the Sixth Fleet was ordered to stand clear of the "combat zone" pending a decision on the Egyptian request. This action, coupled with public statements concerning the possibility of a superpower confrontation, support the hypothesis that Soviet submarines may be operating within the "combat zone" in concert with Libyan forces. Several NATO ministerial meetings have been held since the blockade was instituted. The other NATO members are known to be pressuring the United States to break the blockade in view of the developing economic repercussions of the oil cutback.

Israel labeled the attack on the U. S. merchant ship bound for Haifa an act of war and ordered its navy to prosecute all submarine contacts within 50 miles of the Israeli coast. On 30 March a SAAR PTFG detected and attacked a submarine outside the Haifa harbor. The Soviets claim that Israel attacked a Soviet submarine operating in international waters. Western sources are unable to substantiate the allegation. The USSR admonished the U.S. to "...impress upon the client state of Israel the full impact of its irresponsible action," and warned that "...future unprovoked attacks will elicit appropriate responses...with attendant threats to world peace."

As of 31 March, the Israeli order to actively prosecute all submarine contacts remains in effect. The Soviet Union is rapidly augmenting its Mediterranean force. The Libyan blockade remains in effect, as do the Iranian naval patrols. The ground war continues in Kuwait. The economic crisis in Japan and Western Europe is worsening and the United States is faced with the prospect of a superpower confrontation in the eastern Mediterranean.

B. SCENARIO'S IMPACT ON THE WEST

The scenario projects a crisis in 1980 based primarily on the ability of lesser developed nations to deny portions of the world's oceans to Western ships. Concern over this type of scenario already exists and will probably expand as nations situated in vital geographic areas increase their naval capabilities. Western dependence on Persian Gulf oil production is a reality in 1977 and will probably remain of crucial importance in the 1980 period.

The forces central to the scenario are representative of the rapid build-up of sophisticated naval weapons systems in various geographic regions during the 1970's. The naval forces of the seven nations discussed in the scenario are either on hand in 1977, or are projected to be in place prior to 1980. The naval inventories of the participants are outlined briefly to illustrate the scope of the build-up.[1]

1. Iraq has acquired ten OSA PTFGs from the Soviet Union since 1973. Further deliveries are probable.

2. Kuwait is aware of the possible threat to its coastline and to its increasing tanker tonnage.[2] Surface-

to-surface missile boats are expected to be added to its inventory in the near future.[3]

3. Saudi Arabia has contracted for a major naval expansion program with the U.S. At least some of the ships will be missile-equipped and will be stationed at facilities to be constructed in the Persian Gulf.[4]

4. Iran possesses seven surface-to-surface missile-equipped combatants and has 16 additional units on order from various Western sources. The Shah has contracted for three U.S. diesel submarines. These units will serve as training vehicles for an expanded submarine force.[5] The Iranian Navy has support ships, surveillance aircraft, helicopters and hovercraft (some of which will mount SSMs) which would be useful in a Persian Gulf blockade.

5. Libya owns three missile-equipped combatants and has 42 additional units on order from the USSR and Western sources. Libya has also concluded an agreement with the Soviet Union for up to six FOXTROT SSs. The first of these diesel submarines was delivered in January 1977.[6]

6. Egyptian naval inventories include 12 diesel

submarines and 16 missile-equipped combatants. Egypt has begun construction of ships equivalent to the Soviet KOMAR PTG. Negotiations are underway with British firms for the revitalization of other existing Soviet-supplied missile combatants.

7. The mainstay of the Israeli Navy is its 18 SAAR PTFGs, some of which carry sonars. Six additional units are scheduled to be built in Israel. The Israeli Navy possesses two diesel submarines and three additional units have been ordered from the U.K.

The next chapter is devoted to an examination of Western concerns, the build-up of sophisticated naval combatants in the Third World, and the factors promoting the increase in the naval inventories of lesser developed nations. Chapter III will discuss the limitations of current approaches to quantifying naval arms transfers and will suggest an alternative method (Multi-Attribute Utility Theory) which offers to overcome some of the deficiencies in evaluating naval weapons capabilities.

The following chapters attempt to apply Multi-Attribute Utility Theory (MAUT) to the arms transfer situation with

respect to deliveries of antiship missile combatants and torpedo-firing diesel submarines to Third World nations. Chapter IV details the questionnaire construction process and discusses the procedure used in selecting questionnaire respondents. Chapter V develops the utility curves which form the basis for the technique and applies the curves to specific weapons systems encountered in Third World inventories. Chapter VI is concerned with procedures involved in developing factor scores relating to Third World nations' capabilities to maintain and operate these sophisticated weapons systems. The final chapter presents conclusions and recommendations for future research.

II. SCOPE OF THE THREAT

This chapter describes the threat embodied in the acquisition of antiship missile combatants and diesel submarines by Third World nations. The first section presents concerns as expressed by influential naval spokesmen and highlights the vulnerabilities of crude oil transportation to lesser developed nations' naval forces. The second portion describes post-World War II trends in acquisitions of surface-to-surface missile (SSM) combatants and modern diesel submarines. The final section of the chapter identifies major factors which have contributed to the rapid increase in these weapon systems in Third World inventories and those influences which are likely to affect the trends in the foreseeable future.

A. INCREASED STRATEGIC IMPLICATIONS

The development of lesser developed countries' navies is the subject of growing concern among Western naval planners.

In the past the ability of the United States Navy to provide sea control has been discussed with respect to the interdiction capabilities of the Soviet Navy. However, the expanding inventories of modern naval units in the Third World inject new urgency into the counsel of influential spokesmen who warn that "...the age-old lessons of seapower must be put forward. Those who have the capacity to use those sea routes in safety will survive. Those who have the capacity to interrupt this international intercourse will remain, as always in the past, in a position to achieve their ends."[7]

This somber warning is linked to a growing awareness that in addition to the Soviet threat to sea lanes, "Other coastal nations can temporarily threaten U.S. forces acting in support of the national strategy."[8] Or, as stated in the Forward to Jane's Fighting Ships 1975-76:

> "...A small power possessed of fast attack craft with missiles now occupies a position where it can deny sea areas to the ships of far larger navies...Difficult targets themselves, these craft are possessed of a power of destruction hitherto unbelievable. No major naval power can believe itself invulnerable in the face of such a threat."[9]

The authors succinctly define the apparent paradox in the Persian Gulf scenario, namely the ability of numerically

small naval forces to close vital ocean areas to ships of major naval powers.

"...So we find a strange imbalance amongst the world's navies. The major nations may consider their power, their ability to deploy considerable forces to areas where they wish to exert pressure, as pre-eminent, but the number of localities where such a move could be unopposed is decreasing. The comparative cheapness and simplicity of the counter is making it available to many countries hitherto considered an non-starters in any naval race."[10]

Beyond the direct threat to fighting ships, there is an acute awareness of the threat to Western economic interests embodied in the naval expansion of Third World nations. The former Secretary of the Navy, J. William Middendorf II, identified the degree of U.S. dependence on the seas when he noted, "It is estimated that more than 70 percent of U.S. trade is with nations other than the two contiguous states of Canada and Mexico. And more than 99 percent of our raw materials and overseas foreign trade moves by sea."[11]

The problems facing the West are more precisely defined by Geoffrey Kemp.

"During the 1970's changes in the inter-national system are taking place which suggest that we would be well advised to regain our "geographical sense" and appreciate some of the very real constraints which geography now imposes...The Western industrial countries are becoming increasingly dependent upon the transhipment of scarce raw materials...located in, and moving through, volatile conflict areas...Of special significance to the West is the area in the south

seas...Within this area, control of strategic choke points...must be assigned greater priority in our strategic thinking."[12]

In discussing "the new strategic map" Kemp calls for a southern hemisphere strategy and draws attention to four countries-- Brazil, Iran, India, and South Africa. All of these nations are involved in expanding their missile combatant and/or diesel submarine inventories.

Waterborne movement of crude oil accounts for a major portion of the ocean commerce of the U.S. and its allies. The difficult task of protecting this traffic has been compounded by recent developments alluded to in the Persian Gulf scenario. These factors combine to greatly increase oil tanker vulnerability.

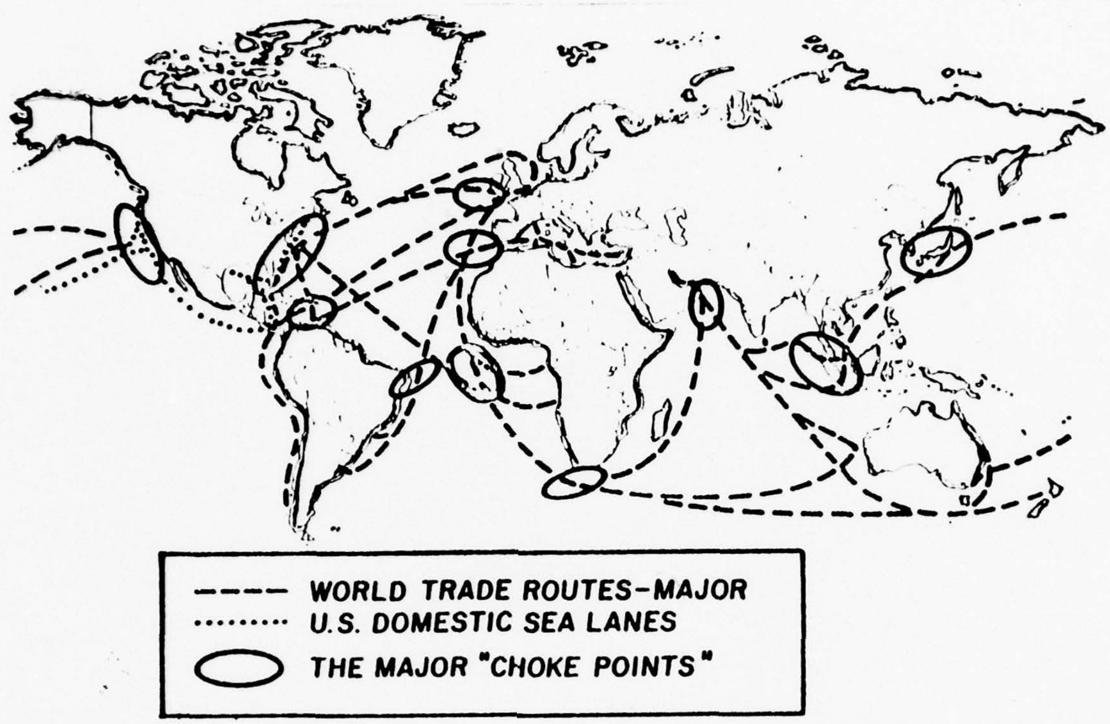
1. There has been a trend toward increasing the size of crude oil carriers. This in turn severely restricts the routes these ships can use. The restrictions create an inflexible system dependent upon narrowly defined sea lanes and increase oil transportation vulnerability to interdiction and disruption. The inflexibility makes the tankers easy targets to find and negates any need for sophisticated locating systems. Thus, the ships are

vulnerable to guerrilla attacks by naval units of relatively unsophisticated navies.

2. The sea lanes transit straits where interdiction of tanker traffic is relatively easy. Figure 1 depicts major sea lanes and identifies choke points through which they pass. The fact that traffic is heavily concentrated in restricted areas, such as the Straits of Hormuz and the Straits of Malacca, raises the credibility of a threat to attack oil tankers and increases the value of interdiction platforms owned by nations located in the vicinity of the choke points.

3. The extreme cost of modern supertankers makes a credible threat to these ships sufficient to disrupt shipping patterns. Private owners of these vessels are not likely to risk their tremendous investments in the face of threats such as the one outlined in the opening scenario.

4. The supertankers have become inviting targets for nations with small naval inventories. The increased size of an average tanker raises the possibility that one well-aimed torpedo directed at one target will have a far greater



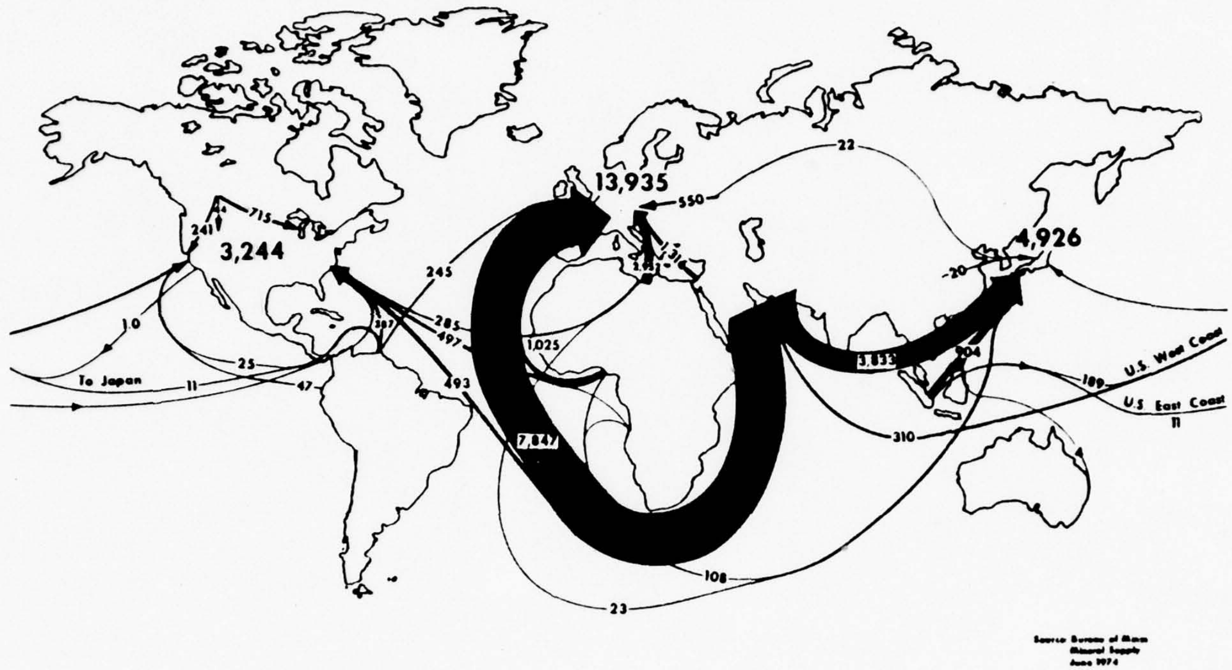
Source: Strategic Aspects of Seaborne Oil, P. 41.

Figure 1 - CHOKE POINTS ON MAJOR WORLD TRADE ROUTES

effect than the anti-convoy operations of World War II.[13] This raises the cost effectiveness of a small submarine force operating in an interdiction role. It is not suggested that a lesser developed nation would be able to completely interdict a major sea lane with the submarine inventories currently on hand. However, sinking even one supertanker would have a tremendous impact on the entire oil transportation system and the Western world in general. Some analysts give navies of lesser developed nations the capacity to interdict vital lifelines and acknowledge that diesel submarines "...could because of random dispersal... have a military value disproportionate to their apparent capability."[14]

The Persian Gulf is the central geographic area in terms of crude oil production and transportation. Countries surrounding the Gulf accounted for 38.5 percent of world oil reserves in 1974.[15] If Saudi reserves are added, the region accounted for 58.1 percent of the known oil deposits. Persian Gulf nations produced 23.3 percent of the crude oil extracted in the same year. When Saudi production is added, the area accounted for 38.4 percent of world production. With the inclusion of vast natural gas deposits found in this area, its importance to Western economic well-being

WORLD CRUDE OIL MOVEMENTS TO MAJOR CONSUMING AREAS - 1973
(thousand barrels per day)



Source: Minerals Yearbook 1973, p. 922.

Figure 2 - WORLD CRUDE OIL MOVEMENTS

becomes even more pronounced.

The effect that closing the Straits of Hormuz to tanker traffic would have on the economies of Europe and Japan is graphically displayed in Figure 2. Reports based on 1976 consumption indicate that the Straits of Hormuz offer a potential interdiction point for 90 percent of Japan's oil, 75 percent of Europe's oil, 70 percent of Australia's oil and 30 percent of U.S. oil imports.[16] Movement of this vast quantity of oil requires that a tanker transit the Straits every eight minutes, 24 hours a day, every day of the year.[17]

The vulnerability of this tremendous oil flow to interdiction is acknowledged. The level of concern is evidenced by the following excerpt from testimony given by the former Chief of Naval Operations, Admiral Elmo R. Zumwalt, Jr., to the Senate Committee on Interior and Insular Affairs in January 1973.

> "...The route is a very long one, some 12,000 miles from Kuwait to New York and most of it passes through areas where U.S. forces have little operating experience and few bases. Mustering the military means to protect this long route would strain our resources severely.
>
> "...The oil exported from the Gulf must pass through the Strait of Hormuz. The Gulf itself is quite shallow and the Straits are generally narrow. This, plus the deep drafts of the supertankers, means maneuvering room for large tankers is quite restricted...Sinking just a handful of tankers in critical passages could effectively block shipments from the Gulf for a long time...there is little the U.S. could now do militarily to forestall this possibility...

"Another possibility is that the tanker shipments might be attacked in the open ocean after they left the Gulf ...To bring any...naval capabilities to bear in the Persian Gulf area could require as much as a month. Our Mideast Force, normally comprising just two or three destroyers, would require augmentation to have significant combat capability."[18]

B. INVENTORY INCREASES

The major capabilities of the navies of lesser developed nations are embodied in surface-to-surface missile-equipped surface combatants.[19] Various authors have noted that "...the proliferations of the comparatively small fast patrol craft armed with missiles must inevitably change the balance of power in many important areas."[20] Firepower increases which accompany the acquisition of these units are evident in the statement that "...the improvement in missile capability now gives a single ship a capacity for destruction only equalled in the past by great fleets and squadrons of aircraft."[21] "Some observers have forecast major changes in naval tactics and in the world balance of naval power as a result of the proliferation of missile-armed patrol boats."[22]

These combatants have demonstrated their capabilities. The 1967 Israeli missile attack on the USS Liberty and the

destruction of the Israeli destroyer "Eilat" by Egyptian SS-N-2/STYX missiles received much publicity. In the 1970 Indo-Pakistani War, Indian OSA PTFGs reportedly sank one Pakistani destroyer and damaged a second with SS-N-2 missiles.[23] The 1973 October War saw the first encounters between antiship missile-equipped combatants. Israeli reports of naval victories over Syrian and Egyptian OSA PTFGs and KOMAR PTGs received wide notoriety.[24] The result has been increased Third World interest in the effectiveness of the Israeli SAAR PTFG and the GABRIEL SSM in particular, and in the acquisition of surface-to-surface missile combatants in general.

There are five basic types of antiship missile systems being built outside the Soviet Union (EXOCET--France, OTOMAT--France/Italy, GABRIEL--Israel, SEA KILLER--Italy, PENGUIN--Norway). All are available for export. The Soviets produce a number of antiship missiles, but export only the SS-N-2/STYX.[25] The U.S. HARPOON SSM is nearing operational status and reportedly will be exported.[26] In addition, some missiles have been converted for antiship use (such as the French SS-12) or adapted to provide an antiship mode (such as the U.S. STANDARD). Most of these systems are small enough to be mounted on combatants currently

operated by lesser developed nations. In addition to retrofitting the systems on small combatants, a number of nations have ordered modern combatants designed specifically to mount these missile systems.

The recent dramatic increase in the number of antiship missile-equipped combatants in lesser developed nations' inventories began in 1961 with the transfer of two Soviet KOMAR PTGs to Indonesia.[27] By 1976, 342 surface-to-surface missile-equipped combatants had been delivered to lesser developed nations. Fifteen units were deleted from various nations' inventories, primarily through combat losses, leaving the active Third World inventory at 327 units at the end of 1976. The upward trend in deliveries and inventories is displayed in Figure 3.

By 1980 at least 217 more antiship missile-equipped surface combatants will be incorporated into Third World inventories. This includes existing orders plus a projection of current PRC production rates of 20 missile units per year through 1980. The figure is understated to the extent that the exact number of missile units to be

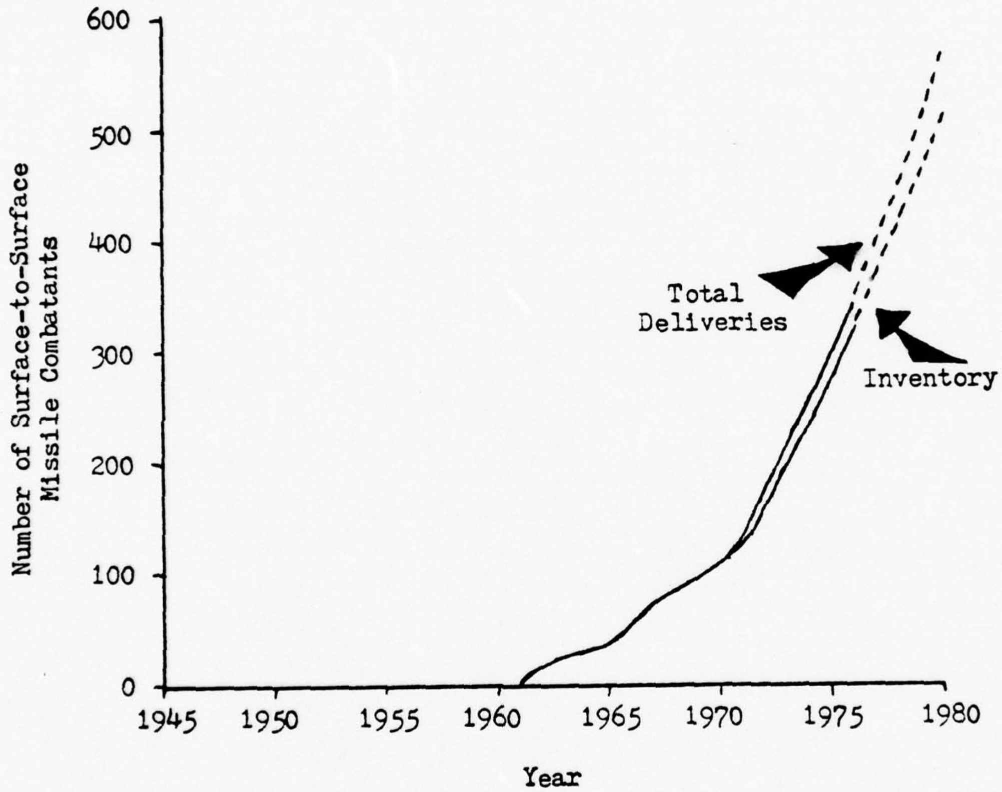


Figure 3 - MISSILE COMBATANT DELIVERY TREND

delivered to Saudi Arabia under the Saudi Naval Expansion Program is not available, and by the fact that additional Soviet deliveries are almost certain to occur during the period. Some missile units may be retired during the 1977-80 time period. Likely candidates for deletion would be older KOMAR PTGs in the inventories of some countries. Even if retirements do occur, deletions will not approach the number of units being acquired during the same period.

Expanding deliveries have been accompanied by an increase in the number of nations possessing missile combatants. By the end of 1976, 30 countries owned this type of weapons platform. Four additional nations (Argentina, Brazil, Saudi Arabia and South Africa) have units on order and will join this group prior to the end of the decade. The growth pattern is displayed in Figure 4.

The missile boat proliferation has been accompanied by an enlargement of the ocean areas within range of missile units. Figure 5 presents nations which possessed surface-to-surface missile combatants as of 1970. Nations which currently have these units are depicted in Figure 6 along with nations scheduled to receive these missile ships prior to 1980.

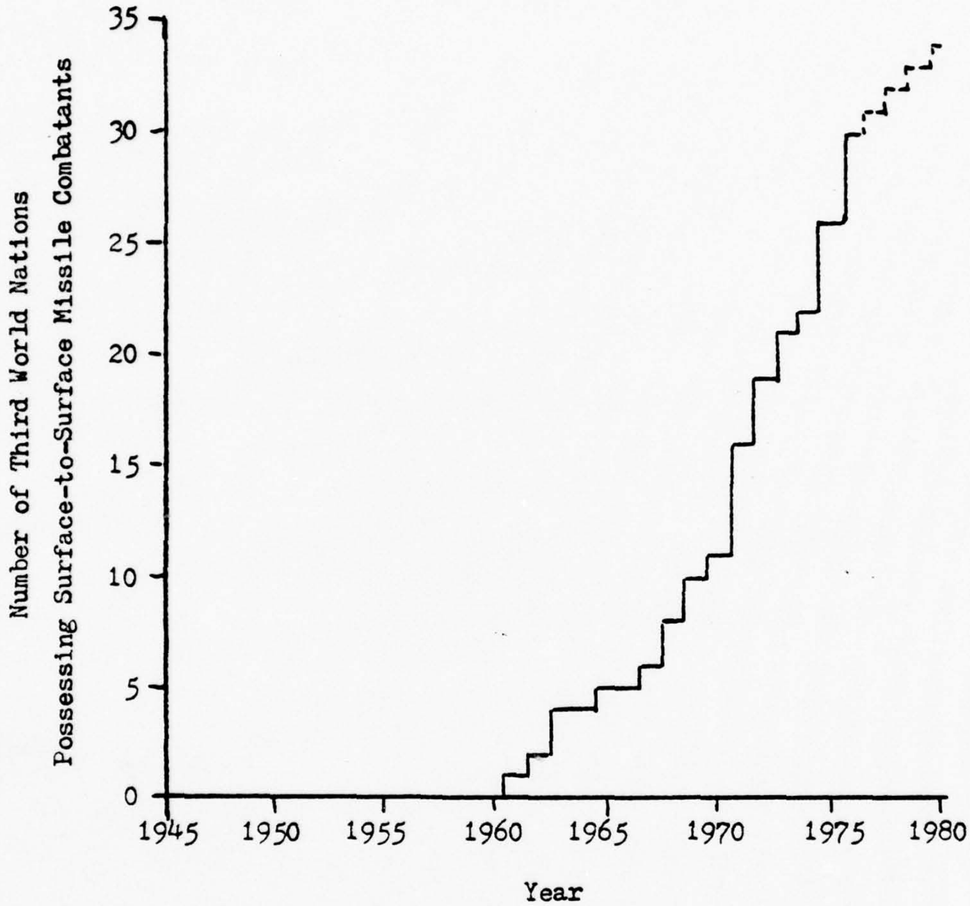


Figure 4 - MISSILE COMBATANT RECIPIENT TREND

Figure 5 - MISSILE COMBATANT RECIPIENTS (1970)

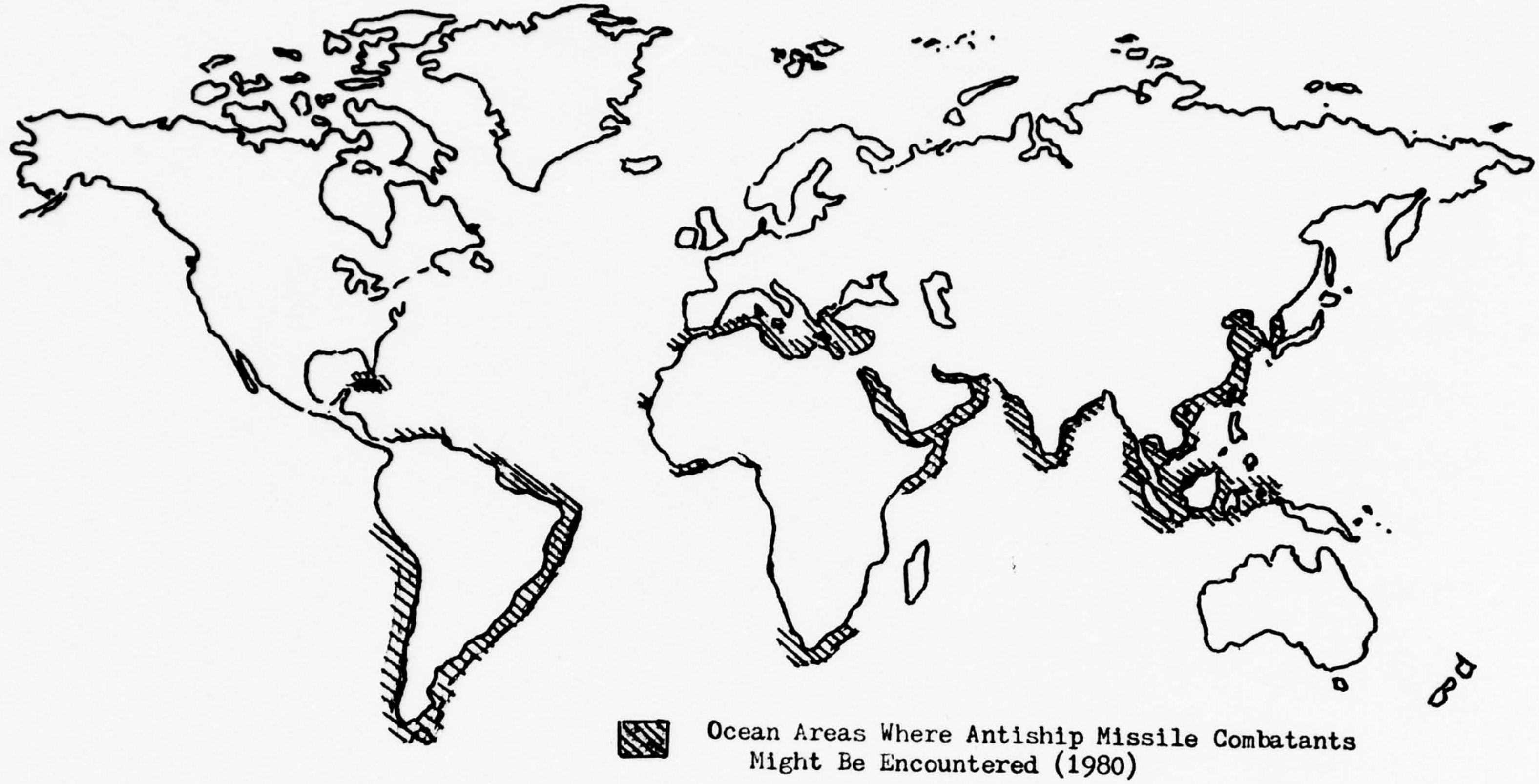


Figure 6 - MISSILE COMBATANT RÉCIPIENTS (1980)

The second group of naval combatants with recognized sea denial capabilities found in the Third World is diesel submarines. The loss of the Indian destroyer "Khurkri" to a Pakistani DAPHNE SS in December 1970 highlights the high level of concern over the capability of lesser developed nations to effectively deploy these units.

Submarine acquisition by Third World nations has shown a less dramatic increase than missile combatant procurement. Initial deliveries took place in the post-World War II period. By the end of 1976, 206 submarines had been delivered to Third World navies. Unlike the missile combatants, a substantial number of units have been retired, so that the current Third World torpedo-firing diesel submarine inventory consists of 158 units. An additional 65 submarines are on order for delivery prior to 1980. Included in this figure are projections that the PRC will continue its current production rate of six ROMEO SSs per year and that the North Koreans will continue to produce two units annually. As was the case with the missile combatants, unannounced Soviet deliveries are possible. Additional retirements are likely as BALAO SSs and Soviet-supplied WHISKEYs reach the end of their usable

lives.[28] The diesel submarine acquisition trends are shown in Figure 7. (Figure 7 is drawn to the same scale as Figure 3 to aid in making comparisons between missile combatant and submarine acquisitions.) However, it must be noted that submarine retirements have resulted in the acquisition of replacements characterized by longer operating ranges, greater submerged endurance, more complex electronics and more sophisticated torpedo loads.[29] So, to some extent the modernization process has resulted in replacing coastal submarines with units having improved open ocean capabilities and increased interdiction potential.[30]

Seventeen nations currently possess diesel submarines and four nations (Ecuador, Uruguay, Iran and Libya) are scheduled to receive torpedo-firing submarines prior to 1980. Figure 8 shows the relatively steady increase in numbers of diesel submarine recipients. As was the case with nations possessing antiship missile-equipped combatants, a number of nations possessing diesel submarines are located in the vicinity of oil lane choke points. Figure 9 displays the geographical locations of the 17 nations which have diesel submarines in their inventories.

Table I summarizes the status of both antiship missile

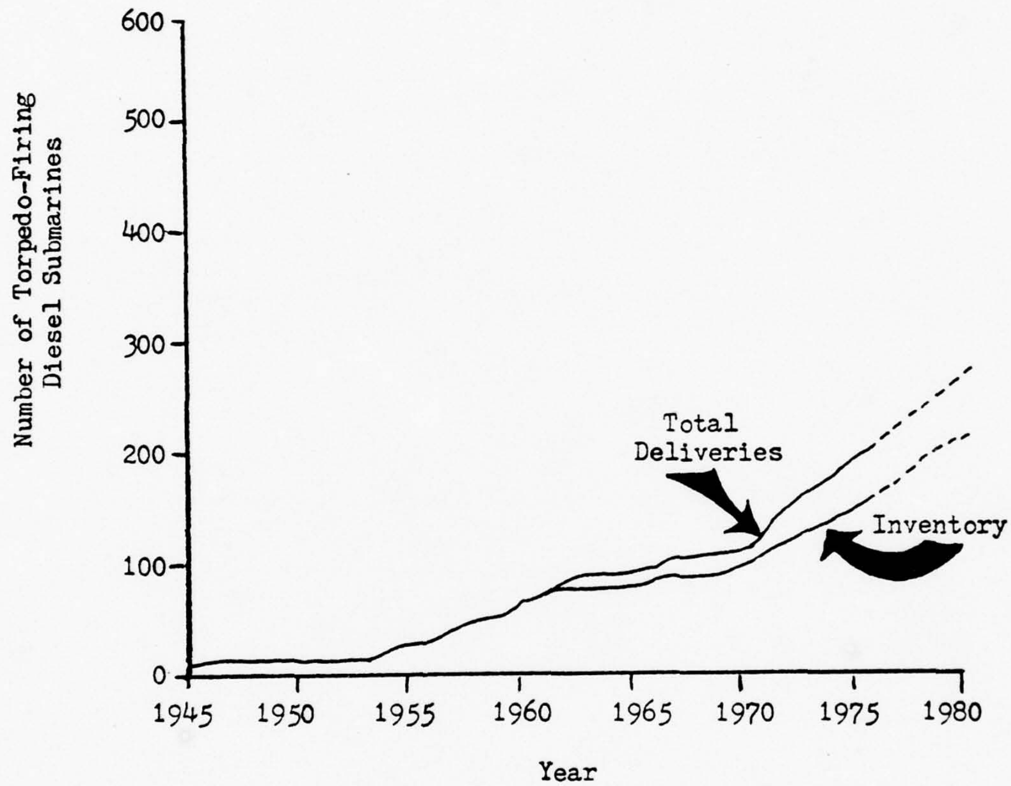


Figure 7 - DIESEL SUBMARINE DELIVERY TREND

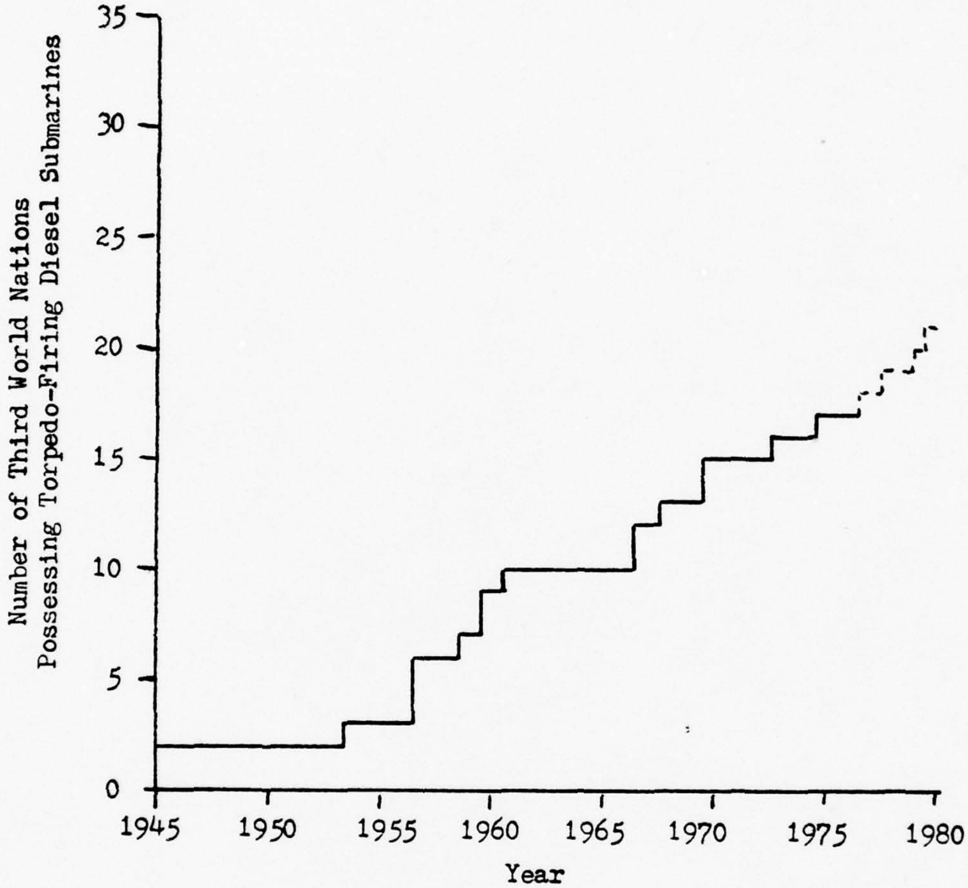


Figure 8 - DIESEL SUBMARINE RECIPIENT TREND

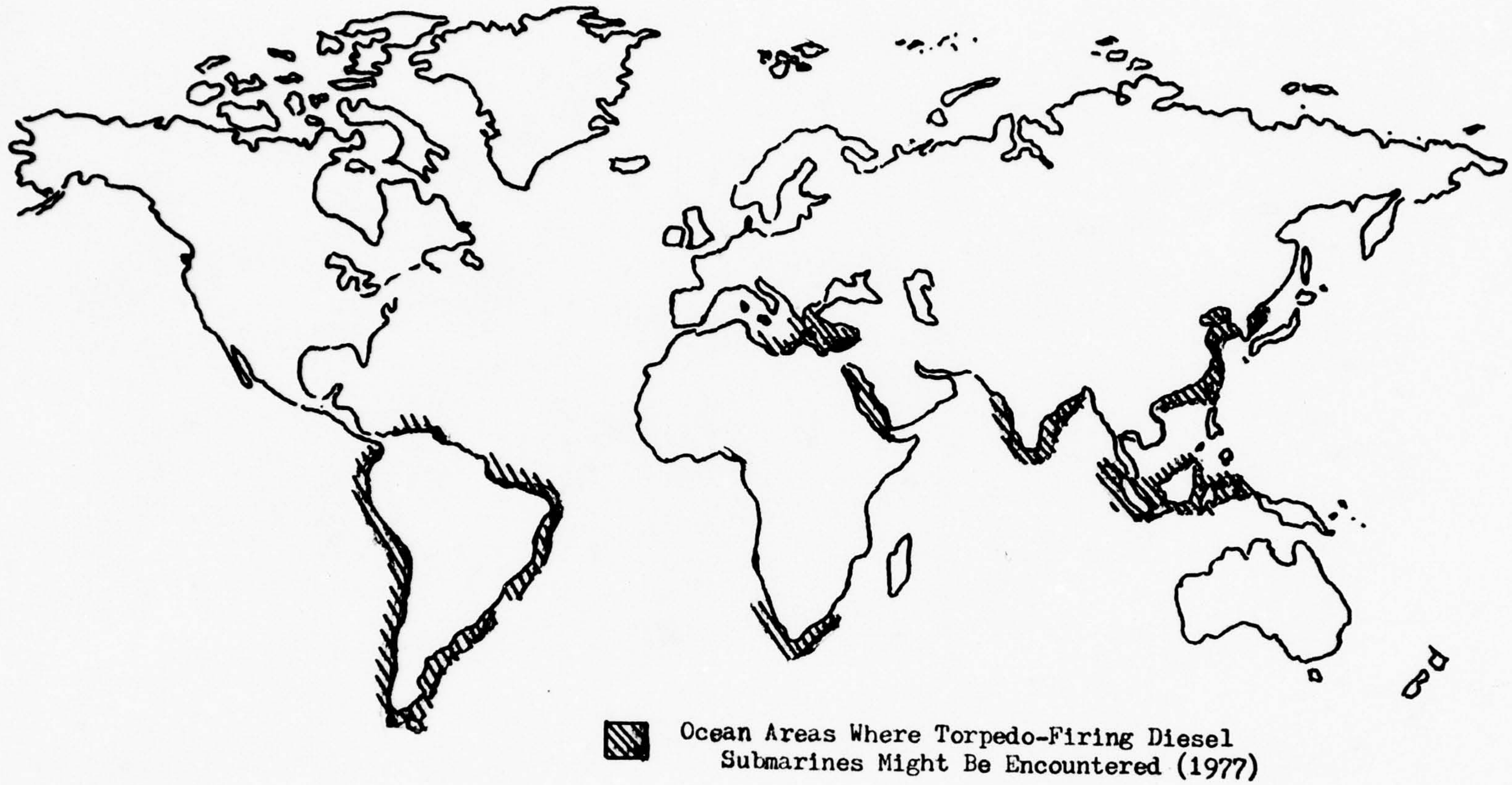


Figure 9 - DIESEL SUBMARINE RECIPIENTS (1977)

TABLE I

THIRD WORLD SEA DENIAL CAPABILITIES

Country	Antiship Missile Combatants		Torpedo-Firing Diesel Submarines	
	On-Hand	Ordered	On-Hand	Ordered
<u>Mediterranean</u>				
Greece	X		X	X
Turkey	X	X	X	X
<u>South/Central America</u>				
Argentina		X	X	
Brazil		X	X	X
Chile	X		X	
Columbia			X	
Cuba	X			
Ecuador	X			X
Peru	X	X	X	X
Uruguay				X
Venezuela	X	X	X	X
<u>North Africa</u>				
Algeria	X			
Libya	X	X	X	X
Morocco	X	X		
Tunisia	X			
<u>Southern Africa</u>				
Ivory Coast	X	X		
Senegal	X	X		
Somalia	X			
South Africa		X	X	X
<u>Middle East</u>				
Egypt	X		X	
Iran	X	X		X
Iraq	X			
Israel	X	X	X	X
Saudi Arabia		X		
Syria	X			
<u>South Asia</u>				
India	X	X	X	X
Pakistan			X	
<u>Far East</u>				
Brunei	X			
China (PRC)	X	X	X	X
Indonesia	X		X	
Korea, North	X		X	X
Korea, South	X	X		
Malaysia	X	X		
Singapore	X			
Taiwan	X	X	X	
Thailand	X	X		
Vietnam	X			

Source: Various (See Appendix A.)

combatants and torpedo-firing diesel submarines in Third World naval inventories.

C. REASONS FOR GROWTH OF NAVAL CAPABILITIES

A number of factors have contributed to the growth of torpedo-firing diesel submarines and surface-to-surface missile-equipped combatants in Third World inventories. These factors are likely to remain operable for the near future. Thus, it is anticipated that the threat to Western economic and military assets will continue to expand.

The following factors are identified because of their influence on Third World weapons procurement. No attempt is made to present an exhaustive listing.

1. Proven operational capabilities in the hands of Third World navies. Egypt and India have demonstrated the effectiveness of a surface-to-surface missile fired at non-missile combatants. Israel has shown the effectiveness of the GABRIEL SSM against combatants mounting the Soviet SS-N-2. This demonstrated capability has lead to a number of arms sales. Prior to the 1973 war, Israel had only

exported the GABRIEL to Singapore.[31] Since 1973 the GABRIEL reportedly has been introduced in South Korea,[32] Thailand,[33] and Taiwan.[34] GABRIELs were ordered by Argentina in 1974.[35] In 1974 South Africa decided to purchase the GABRIEL and the RESHEF/SAAR IV PTFG, rather than purchase Portuguese and French corvettes carrying the French EXOCET missile.[36]

2. Requirement to replace aging World War II surface ships and submarines. A number of Third World nations have received World War II vintage ships and submarines from the U.S. and West European sources. Rather than replacing these aging systems with conventional destroyers and frigates, these nations have generally chosen to acquire smaller, missile-equipped combatants. Some nations, such as Argentina, Brazil, and India, are replacing obsolete units with ships of comparable size carrying surface-to-surface missiles.[37] The identical obsolescence problem is confronting nations which possess aging submarines. These nations have ordered modern submarines like the West German TYPE 209 SS and TYPE 206/500 SS as replacements. The resulting submarine fleets have longer ranges, improved maintainability and a greater degree of sophistication.

3. Improved abaility to pay. Economic considerations

are central to the overall arms transfer situation. They are also applicable to the expansion of sophisticated naval weapons systems in the Third World. Two examples demonstrate the financial commitment being made on the part of some Third World nations. Iran is spending $338 Million on each of four U.S. DD-963's it has ordered[38] and intends to construct a $2 Billion naval base at Chah Bahar close to the Pakistani border.[39] Saudi Arabia will expend in excess of $1 Billion for ships, training and facilities associated with the Saudi Naval Expansion Program now underway.[40] Most of the naval arms transfers represent sales, rather than grants or aid. Prices remain competitive because of active marketing by suppliers. Missile systems in particular are relatively inexpensive.[41] Most of these missile systems can be mounted on a variety of combatants already in Third World inventories to further reduce system costs.

On the other hand, diesel submarine purchases represent major outlays. For example, recent estimates place the cost of West German-built TYPE 206/500 submarines at $15 to $21 Million each.[42] Also, there is less competition between suppliers, since only France, West Germany and the U.K. are producing new units for export and only the U.S. and USSR are involved in transfers of reconditioned units. Financial

considerations may largely account for the relatively small number of lesser developed submarine recipients.

4. Existence of offshore disputed areas. Resources located in offshore areas are increasing in value and are becoming more exploitable as a result of technological advances. For example, offshore oil deposits account for approximately 20 percent of world reserves. New drilling technologies allowing exploitation at greater depths are expected to raise this percentage significantly.[43] Oil-rich areas under dispute between nations with surface-to-surface missile combatants and/or diesel submarines include: the Spratley and Paracel Island areas (PRC, Vietnam, Taiwan), the Persian Gulf (Iran and Iraq) and the Aegean Sea (Greece and Turkey).[44] These disputes generate requirements for naval forces capable of protecting national claims to the resources. Additional requirements are probable as exploitation and exploration techniques identify additional resource-rich ocean areas.

5. Extension of national economic zones. Proposals to extend national economic zones out to 200 miles have been introduced at the Law of the Sea Conference. Failure of the Conference to act upon these proposals has led to a series

of unilateral declarations of 200-mile economic zones. Expanded economic zones would provide impetus for enlarging naval forces and extending naval operating ranges to permit patrols out to the 200-mile limit. Present Law of the Sea proposals will probably promote a trend established by early proponents of enlarged territorial waters. In 1970 Argentina and Chile were early advocates of 200 mile fishing zones.[45] Both have since acquired and/or ordered sophisticated submarines and missile combatants with extended ranges. Seven nations (Argentina, Brazil, Ecuador, El Salvador, Panama, Peru and Uruguay) were early supporters of vastly increased territorial waters. Of this group, three (Argentina, Brazil and Peru) have received and/or ordered destroyer-size missile ships with extended ranges. Five (Argentina, Brazil, Ecuador, Peru, Uruguay) have ordered and/or taken delivery of sophisticated submarines (TYPE 209 and OBERON SSs) since that time. This preliminary data suggests a correlation between support for extended economic zones and a perceived need to upgrade the firepower and operating ranges of naval forces. Further expansion of the size, range and sophistication of Third World naval combatants and a proliferation in the number of recipients could follow the move toward the 200 mile norm.

III. QUANTIFYING SEA DENIAL CAPABILITY

This chapter examines various methods for quantifying military worth of weapons systems in an attempt to describe the capabilities and limitations of each approach. The first portion of the chapter examines the numerical/inventory approach used in Chapter II. The second section outlines some alternative methods for dealing with the subject of capabilities analysis and describes one recent approach to the problem of developing capabilities scores. The final portion of the chapter discusses Multi-Attribute Utility Theory and potential usage of this approach in military capability measurement.

A. NUMERICAL/INVENTORY APPROACH

The numerical/inventory approach to quantifying arms transfer issues is one of the more popular methods currently in use. It offers many of the advantages of quantification discussed in connection with measurement in the policy

sciences.[46] The technique is useful in discussions of the type presented in Chapter II where the purpose is to provide background information and to alert the reader to a threat. Since the unit of measurement is the weapon system itself, the approach can provide an accurate accounting for the volume and direction of arms traffic.

The method is often over-used and incorrectly applied. It is incapable of describing qualitative differences between various platforms within a class of weapon systems, since the unit of measure (in the present case either missile combatants or diesel submarines) does not embody any general attribute or characteristic upon which to base comparisons.[47] So, for example, under the inventory approach, a KOMAR PTG and an OSA PTFG would each count as one missile ship regardless of the fact that the OSA carries twice as many missiles as the KOMAR. There is a qualitative characteristic (firepower) which clearly differentiates the KOMAR from the OSA. However, the numerical approach cannot distinguish between the systems. Since the method cannot make this type of distinction, it is not an appropriate measure of military balance or military capability.

This limitation would appear to be obvious. Still, The

Military Balance series published by the International Institute of Strategic Studies (IISS) advertises itself as, "...a quantitative evaluation of military power..." even though it is based entirely upon a tabulation of force levels.[48] Also, U.S. Government spokesmen regularly offer inventory figures as a basis for arms transfer decisions in situations where considerations of military balances are of prime concern. For example, during the mid-1976 Congressional hearings concerning Saudi Arabia's request for SIDEWINDER air-to-air missiles, the U.S. Arms Control Agency endorsed the proposed sale of 1500 SIDEWINDERs with the statement that, "...the risk of conflict between Saudi Arabia and neighboring states is unlikely to be affected by this number of missiles."[49] No mention was made of Saudi military requirements, nor was there a discussion of any increase in military capabilities which might accompany the transfer of 1500 missiles. Moreover, decision makers appear to make policy choices based on numerical approach-generated figures. In the SIDEWINDER case, Congress permitted the sale of 1500 precision-guided missiles to Saudi Arabia. "Under a compromise agreement worked out with key Senators, the State Department and the Pentagon, the proposed sale was fixed at 850 SIDEWINDER air-to-air missiles and 650 MAVERICK TV-guided missiles."[50]

The demonstrated attachment to inventory counting may derive from the fact that it is relatively simple, unambiguous and easily accomplished by staff personnel. There is little doubt that the information compiled in this manner is misused. If the policy maker has a background permitting him to comprehend the subtleties of the systems involved, inventory figures might be correctly applied. However, there are few decision makers with this analytic knowledge.

There is a clear need for a measure of military worth which can be constructed by analysts and operators who possess an intimate acquaintance with the weapons being evaluated. The technique must be both reliable[51] and valid.[52] It must also offer meaningful information to the policy maker faced with the difficult issues attached to arms transfer decisions and considerations of military balance and regional stability. These stringent conditions are not easily met.

B. ALTERNATIVES TO NUMERICAL/INVENTORY QUANTIFICATION

The hazards involved in applying the numerical/inventory

approach to capability measurement have produced attempts to develop alternative quantification techniques. One method seeks to measure military capability by addressing the dominant system characteristic in order to avoid "...simple number calculations (which) necessarily overlook relative qualitative weapons system features."[53] Eldridge constructs an index to measure Third World sea denial capabilities by multiplying the number of platforms of a particular type times the number of missile launchers/torpedo tubes carried by that platform.[54] He aggregates these scores to determine the sea denial capabilities of a Third World navy's missile boat/diesel submarine forces.

Although the technique overcomes the major deficiency in the inventory approach by addressing a qualitative difference (firepower), it fails to describe the wide variety of factors which bear on successful accomplishment of an anti-shipping mission. For example, the Eldridge method would scale a BRAVE PTGL which carries eight SS-12 wire-guided missiles above a LA COMBATTANTE II PTFG mounting four EXOCET SSMs. The fact that the SS-12 has a range of 3.5 NM and that the EXOCET has a 22 NM range would never be considered.[55] All other missile characteristics which might similarly bear on mission success are ignored in the same

way. The approach completely ignores ship's characteristics which may make a major contribution to performing a given mission.

Other students of arms transfer issues have attempted to avoid inventory-related approaches by utilizing a dollar-value measure. (Both the Stockholm International Peace Research Institute "SIPRI" and the Arms Control and Disarmament Agency "ACDA" rely on this approach). The method is based on cost, "...the basic assumption being that an increase in cost (in real terms) buys an increase in performance or capability."[56] This approach is intuitively appealing, but it has major flaws deriving from difficulties in using monetary value as a precise indicator of qualitative differences. Valuation problems, uncertainties in pricing foreign arms transfers (especially those from communist nations), difficulties in dealing with grants and/or special financing arrangements and problems in pricing arms transferred out of surplus stocks all contribute to the difficulties with the method.

Inherent difficulties with the popular quantitative techniques discussed to this point prompted LT Alan LeGrow to examine alternative approaches to measuring military

worth. In his thesis, <u>Measuring Aircraft Capability for Military and Political Analysis</u>,[57] LeGrow discusses possible methods for quantifying capability and presents four scaling techniques-- factor analysis, paired comparisons, successive intervals and multi-attribute utility scaling. He examines the theoretical basis for each and identifies individual strengths and weaknesses. He then scales aerial combat capability of fighter aircraft using each method in turn. LeGrow concluded that factor analysis could be a valuable tool for military capabilities analysis allowing incorporation of computer processing into a research effort. However, he noted that much faith has been placed in this approach due to its applications in data analysis, without the requisite attention being paid to the difficult implimentation tasks which must accompany its use in capabilities analysis. He found that judgmental scaling techniques offer viable alternatives to the more structured factor analytic approach. The successive intervals method demonstrated greater sensitivity to the responses of expert judges than paired comparisons. However, the successive intervals method suffers from an inability to measure system capabilities where one system is generally agreed to be either superior or inferior to another given system. The problems with these scaling techniques led LeGrow to

examine, and suggest further analysis of, the capabilities of Multi-Attribute Utility Theory as an analytic tool.

A recent discussion of arms racing in the Middle East highlights many of the difficulties involved in quantifying military capabilities which have been discussed in this chapter.[58] The author of the article attempts to develop "...a comprehensive set of inventory, capability and manpower data"[59] in order to construct military capability indices for Middle Eastern countries. Rattinger rejects the capability indices which are based upon factor scores[60] in favor of scores for major air, ground and naval systems based on "...the simple product of speed, payload, and combat radius."[61] The author has difficulty applying "payload" to ships, so "...all ships are therefore rank ordered on a scale of 1 (for lowest) to 8 according to main armament, and the rank of each ship was treated as its payload score."[62] Capability scores were then multiplied by inventories and aggregated into national military capability scores which form the basis for Rattinger's study.

This December 1976 article is emphasized here for a number of reasons. First, it demonstrates the growing realization that measures of weapon system capabilities and

accurate inventory figures are both necessary to meaningful study of military balances. Second, the article is indicative of the unsophisticated nature of military capabilities measures currently being applied. Finally, Rattinger invalidates his scale by elevating ordinal-level data[63] to interval-level[64] and performs an operation requiring ratio-level data[65] by multiplying interval-level capability scores by inventory numbers. The failure to differentiate between interval and ratio-level data is a continuing problem in arms transfer analysis. Many researchers wish to measure country capabilities to make comparisons between countries. This ultimately involves multiplying system capability indexes by the numbers of systems of the particular type contained in the nations' inventories. Multiplication is not permitted with interval-level data because of its arbitrary unit and arbitrary origin characteristics. Clearly, an invalid score based on simplistic criteria is not the answer to the decision maker's complex problems.

C. MULTI-ATTRIBUTE UTILITY APPROACH

It is often desirable to move from the side-by-side

comparison of weapons capability permitted by interval-level scaling techniques to a comparison of the military capability of one country with another. An effort is currently underway to develop a model to measure total Soviet force effectiveness to improve "...the credibility of long-range forecasting for defense intelligence estimates and planning."[66] The Soviet Force Effectiveness Model calculates theoretical weapon effectiveness (TWE) measures for over 200 weapons described in the Defense Intelligence Projections for Planning (DIPP). TWE takes into account measures of weapon lethality, accuracy and survivability derived from a complex set of computer manipulations. The TWE is then multiplied by force levels to generate theoretical force effectiveness (TFE) measures. "In addition to aggregating force levels and force characteristics...the model permits the user to aggregate the weapons by several missions."[67]

The same types of calculations would aid in assessing the sea denial potential of the nations depicted in the opening scenario. For instance, it would be useful to compare the naval capabilities of Libya and Egypt to better evaluate Egypt's need for Western military support to break the Libyan blockade. Also, at times it is useful to know

the degree to which one weapon system's capabilities exceed another's. Again referring to the scenario, how much better is an Iranian LA COMBATTANTE II PTFG than a Saudi missile combatant? In this light, what are the Saudi Navy's capabilities to open Persian Gulf resupply lines?

These calculations require ratio-level measurement of weapons' capabilities. While both the dollar-value and inventory approaches provide ratio measures, they are inapplicable for the reasons already discussed. The factor analytic, paired comparison and successive interval methods all provide interval-level measurement. Thus, there is a definite need for multi-attribute utility's (MAUT) ability to produce a ratio-level measure of weapons capabilities. It does so by using utility curves which have a natural origin as building blocks for developing system capability scores.

A second important feature of MAUT is its ability to base analysis on multi-faceted definitions of capability. It offers to avoid simplifications required by the numerical/inventory approach, the Eldridge method of measuring firepower, and Rattinger's measure based on payload, speed and combat radius. MAUT permits analysis of

a wide range of factors which, when combined, would allow a more sophisticated treatment of complex weapon systems' military worth.

Before addressing MAUT in some detail, it is necessary to carefully delineate where the present study should be located on Bode's "Dialectical Hierarchy of Interactions."[68] MAUT fits into the category which Bode terms "ex-ante" assessments.[69] These ex-ante, or static, measures "...assess starting conditions only, and relate to what could happen, not what does happen in the real world..."[70] Bode notes that "...strong incentives remain for developing static indices that are sufficiently general to serve as rules of thumb for comparing forces,"[71] and feels that such indices are "...very useful supplements to the intuition of the decision maker and analyst when structuring problems, identifying alternatives for detailed consideration, and checking obscure analysis."[72] MAUT is part of "...efforts to develop Military Effectiveness Indices (MEI) that are suitable for direct calculation of relative military effectiveness without recourse to more complex war gaming."[73] Thus, it seeks to evaluate operational and engineering factors which determine weapon capabilities, without explicitly considering an "enemy" and the two-sided

combat situations required for dynamic modeling. As a result, MAUT cannot, and does not seek to, predict outcomes of engagements between specific types of naval combatants nor battle outcomes between various nations' naval forces.

1. Theory

Utility or value theory is designed to facilitate decision-making. It assumes that a decision maker will act to maximize utility within his set of goals and constraints. Utility theory requires that all possible decision outcomes be quantified, that the utility of each be defined and that the decision be based on maximizing utility. Utility curves, which assign a real value to each possible outcome, are central to the process.

Two important points must be emphasized with respect to the derivation of these curves.

a. The utility function depends on the <u>subjective judgment</u> of the decision maker and on his perception of the environment and the decision objectives.

b. The utility function, once defined, acts as an evaluative scale by which all possible outcomes can be measured.

2. Application

Utility theory was developed and exhibited its earliest applications in the social sciences. The applicability of the theory is now being examined in a broader range of decision-making contexts. RAND Corporation has applied utility theory in an interactive computer program to aid a tactical commander in maximizing the utility of his forces in simulated strikes on Warsaw Pact airbases.[74] Utility functions have also been considered in the context of the treaty negotiation process.[75] This application seeks to develop utility curves to represent the importance attached to each issue by each side and to define a set of possible treaty outcomes which would allow a mediator to quickly evaluate potential treaties and assist in developing the treaty which is "best" for both sides.

A model for employing MAUT is suggested in the process utilized by design engineers to optimize system

design and maximize system worth. "While the purpose of the...analysis is finding an optimal system to fulfill an objective, the solutions obtained can also be used to <u>evaluate or scale</u> existing systems. In other words, the optimal solution can be considered as an ideal model against which all other systems can be judged."[76]

The LeGrow thesis applies MAUT to fighter aircraft and demonstrates a degree of subtlety which is impossible with the other techniques considered. For example, he uses experts to develop utility scores for the MIG-21 and the F-4E. The scores show the MIG-21 to be the superior fighter platform. He then applies values from curves developed by experts for pilot proficiency and country technological capability. When combined with the platform utility scores, the Israeli F-4E for example, demonstrates a higher utility than an Egyptian MIG-21. None of the other techniques have the ability to consider such a broad range of characteristics, nor to consider personnel factors which are crucial to system performance.

If the user accepts the assumptions needed for ratio-level measurement,[77] utility scores for a nation's inventory can be developed by multiplying numbers of

platforms by their respective utility scores and summing. Thus, for example, it would be possible to scale the utility of Saudi Arabia's and Iran's missile boat forces in a sea denial scenario.

Arms transfer calculations are also possible with MAUT. For example, it would be useful for a decision maker to be aware of the utility of Saudi missile boats compared to the utility of the Iraqi OSA PTFGs if he were faced with a request from the Saudis for additional units. If the policy maker desired parity between the forces' capabilities, MAUT could identify the approximate number of boats required by the Saudis to achieve a balance. The theory could also suggest a rule-of-thumb for future arms transfer decisions as Iraq receives additional units from the USSR. Thus, MAUT calculations might provide a meaningful determination of military balance.

The LeGrow examination of MAUT was done at the theoretical level. He demonstrated the technique's potential based on the inputs of two judges and suggested further study of judgmental scaling in general, and of MAUT in particular. The remainder of this thesis attempts to apply MAUT to the missile boat/diesel submarine problem set

forth in Chapters I and II. The goal is to expand and evaluate this promising approach through practical application to a current problem of naval interest.

IV. QUESTIONNAIRE PREPARATION

Ward Edwards, Marcia Guttentag and Kurt Snapper present a concise study of the role of evaluative research in the decision-making process in their article, "A Decision-Theoretical Approach to Evaluation Research." [78] The authors assume that a decision maker is normally amenable to considering evidence which bears on his decision options and that he rarely delegates his decision-making function to a researcher. This requires that researchers develop techniques presenting concise, meaningful analysis which considers the multi-dimensional nature of most real-world decisions. Due to this multi-dimensional aspect, the authors reject a number of possible research techniques in favor of multi-attribute utility measurement. The article extends previous work done with MAUT and presents a practical application which "...is oriented toward easy communication and use in environments in which time is short and decision makers are numerous and busy. Further, it is a method that is psychologically meaningful to decision makers, who are required to give judgments that are

intuitively reasonable." [79]

In the course of the article, the authors develop a blue-print for application of MAUT. Their outline is applied to an examination of the Department of Health, Education and Welfare's Office of Child Development. Circumstances surrounding their evaluation closely parallel many aspects of the study of proliferating Third World sea denial capabilities. In both cases decision makers within the executive and legislative branches are numerous and are under extreme time pressures. Both problems are multi-dimensional and are not adequately dealt with by existing measurement systems. Their outline has been used as a framework for this and the following chapter.

Figure 10 presents a block diagram adapted from the Edwards et al. article which describes the flow of the current study. In the diagram rectangles enclose operations conducted in the course of the study and circles contain informational inputs and outputs from operations. Each of the operations and informational inputs/outputs will be described in detail with the aid of a ten-step procedure also adapted from the Edwards article. The first five steps in the process involve the information collection phase of

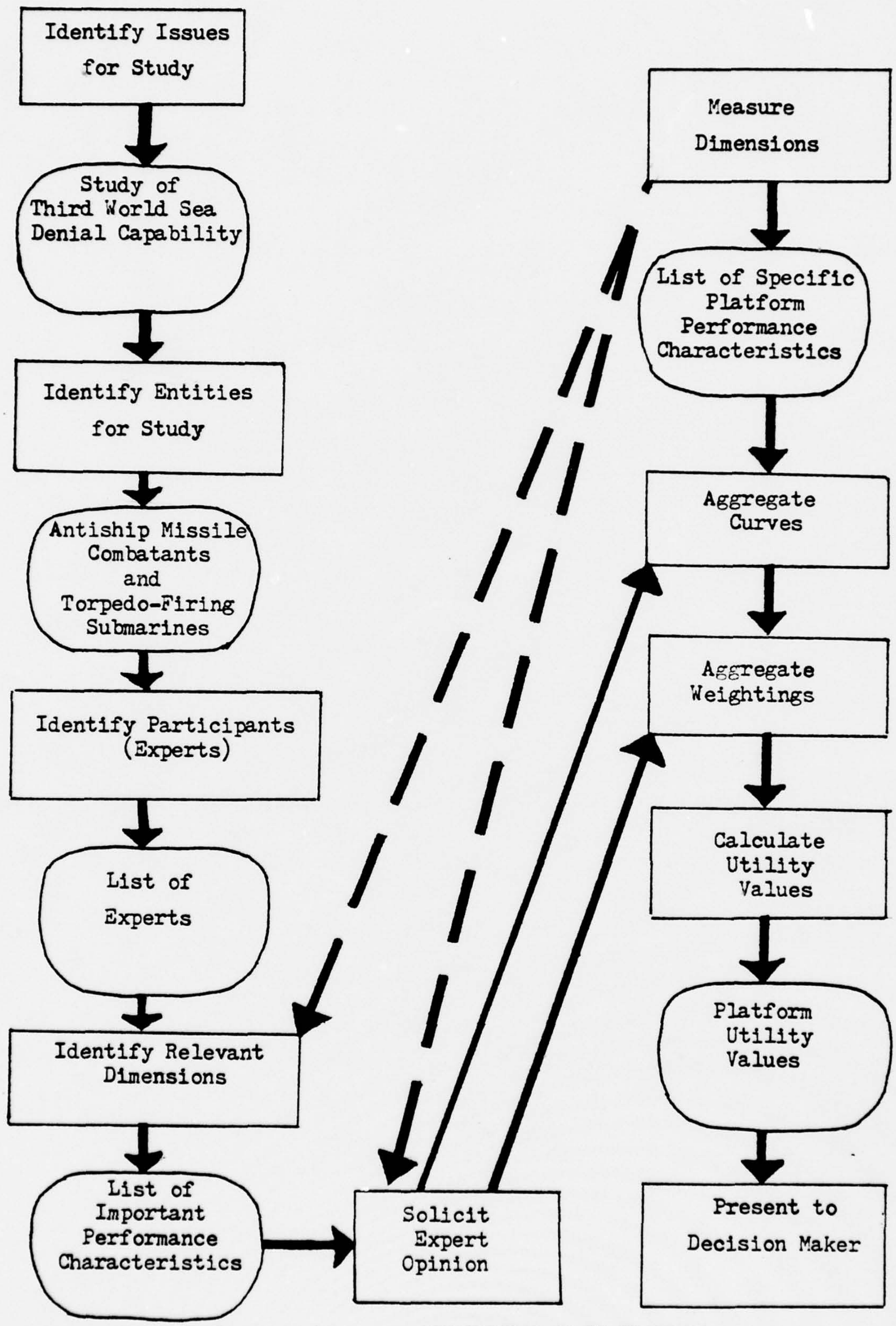


Figure 10 - PROCEDURAL FLOW DIAGRAM

the study and will be presented in this chapter. The remaining five steps concern aggregating information and applying aggregated judgments to existing naval systems. The final five steps are the subject of Chapter V.

A. STEP 1--IDENTIFY ISSUE(S) FOR STUDY

The sea denial capability of Third World nations is the issue being studied. Concerns generated by recent Third World naval expansion programs were presented in Chapters I and II. No further discussion of trends among lesser developed nations is required. However, the importance of this type of examination cannot be overstated. It is essential that the researcher develop a thorough appreciation of the central issue and its ramifications. Without this solid foundation it is impossible to conduct a meaningful investigation of the type of complex real-world issues presented in an evaluation of sea denial capabilities.

B. STEP 2--IDENTIFY ENTITIES TO BE EVALUATED

There was general agreement among naval spokesmen that anti-ship missile surface combatant and torpedo-firing diesel submarine acquisitions by Third World nations represent the greatest sea denial threat. Because these two naval weapons systems provide the basis for Third World sea denial capabilities, they are the entities which will be evaluated in this study. Again, adequate discussion of the expert's concerns was contained in the preceding chapters. No elaboration is required, except to note that once again the researcher must be well acquainted with the issue involved in order to identify the central entities.

C. STEP 3--IDENTIFY PARTICIPANTS

Multi-Attribute Utility Theory depends upon subjective judgments of experts to develop utility curves. The dominant consideration is that the participants possess expertise which will allow them to make the required judgments. The theory is not dependent upon large sample sizes.

Quantifying the military worth of anti-ship missile combatants and diesel submarines required the involvement of

two distinct groups of experts. Since judges with the required expertise were not available at the Naval Postgraduate School, opinions had to be elicited through questionnaires. Judges for the anti-ship missile sea denial questionnaire were drawn from the relatively small number of persons within the U.S. Navy with experience in anti-ship missile combatants, personnel involved in the HARPOON SSM development program, and analysts dealing with the anti-ship missile threat.

The anti-ship missile combatant questionnaire was eventually distributed to 18 individuals. Six of the persons had operational experience with anti-ship missiles and/or surface-to-surface missile combatants. Six were involved in U.S. Navy SSM development programs in a variety of capacities. Six recipients were analysts who evaluate the anti-ship missile threat to the U.S. Navy.

The diesel submarine questionnaire was eventually distributed to fourteen persons. Three are officers currently assigned to U.S. diesel submarines. The remaining eleven officers have served aboard U.S. diesel submarines within the last two years.

The limited number of available experts placed special pressures on the questionnaire construction process involved in Step 5. Additional persons at the Naval Postgraduate School were utilized in Steps 4 and 5 in order to ensure that the questionnaires which were developed were effective instruments for measuring the relevant dimensions of the issue. Their participation will be outlined in the remaining portions of this chapter.

D. STEP 4--IDENTIFY RELEVANT DIMENSIONS

The relevant dimensions are weapon system performance characteristics which determine sea denial potential of systems under study. Had expertise been more readily available, a group of judges might have been gathered to develop the utility curves, or alternatively, to assist in questionnaire construction. The lack of accessible expertise forced the researcher to examine available information concerning SSM-equipped combatants and diesel submarines and to develop a list of performance characteristics normally associated with the systems under study. The lists were discussed with knowledgeable individuals available at the Naval Postgraduate School. The

anti-ship missile combatant characteristics were presented to two officers who had commanded ASHVILLE PGs and two officers with knowledge of naval missiles. Two officers with attack submarine backgrounds were consulted concerning the submarine characteristics. The conversations lead to a number of deletions and additions of criteria deemed important to a comprehensive study of the military worth of these systems.

One example was the attempt to determine the best measure to describe a surface combatant's seakeeping qualities. Seakeeping is difficult to quantify, but it is very important in evaluating the open-ocean capabilities of the relatively small platforms which are common in Third World navies. The preliminary list contained a number of measures regarding ship size--length, beam, draft and height of superstructure. All of these measures bear on seakeeping. However, the former ASHVILLE PG commanders maintained that standard platform displacement presented the best measure of platform seakeeping. This was a particularly attractive measure from the researcher's viewpoint, because it is easily quantified and aggregates a number of physical characteristics into one measure. Aggregated measures were particularly important to

developing a concise questionnaire which would promote a high response rate from the judges. The consultations developed a set of matrices which paired relevant dimensions with measurable performance criteria. Table II presents the

TABLE II

ANTI-SHIP MISSILE COMBATANT MATRIX

Relevant Dimension	Measurable Performance Criteria
Ship Performance	Maximum Sustained Speed
	Range at Maximum Sustained Speed
Seakeeping	Standard Displacement
Radar Capability	Maximum Radar Acquisition Range
Firepower	Number of Missile Tubes
	Missile Hit Probability
Defensive Capability	ECM/DECM Equipment
	Anti-ship Missile Defense Systems
Missile Performance	Maximum Effective Range
	Missile Speed
Destructive Capability	Missile Warhead Size
	Fuzing Configuration
Resistance to Countermeasures	Missile Guidance System
	Home-on-Jam Capability

matrix which resulted from the anti-ship missile combatant discussions.

Two important tendencies became evident during the series of discussions. The first was a desire to tie general performance characteristics to specific weapons systems. While this proclivity demonstrated the individual's previous experiences, it held the potential for eliciting prejudgments that could affect questionnaire responses. There was a demonstrated penchant to focus on the threat from Soviet-built systems, while disregarding systems exported by Western European nations with which the individuals were less familiar. Weapon performance criteria were not associated with specific weapon systems in the questionnaire to avoid this inclination to heavily weight Soviet systems.

The second tendency was to tie discussions of performance criteria to specific scenarios. Much of the consultation time concerned probable Third World employment of the weapon systems. The scenario-dependent nature of these discussions required that the questionnaire outline scenarios consistent with demonstrated Third World navy capabilities which would aid the respondent in making

meaningful judgments.

E. STEP 5--SOLICIT EXPERT OPINIONS VIA QUESTIONNAIRE

The process of developing questionnaires which would be valid measures of military worth began with constructing relevant scenarios. Two separate scenarios were developed for each questionnaire. The first missile boat scenario outlined guerrilla attacks against either merchant ships or non-missile surface combatants. It described the threat which concerned various spokesmen in Chapter II and was in keeping with the surprise attacks against the USS Liberty and the Israeli "Eilat" in 1967. This scenario required the missile boat to transit to normal sea lanes or ocean operatng areas for the attack. Past patterns suggested that the attacker would make maximum use of surprise by conducting a high speed attack, possibly at night. The scenario assumed that air cover was not available for either early warning or target localization/identification.

The second anti-ship missile scenario addressed a war-at-sea situation in line with naval engagements which took place in October 1973. As was previously discussed,

MAUT is not a combat modeling tool. However, it was useful to consider the capabilities of various platforms in a one-on-one situation in an effort to quantify the typical naval balance considerations. Again, the scenario assumed that neither side had air support and that the engagements tested the open ocean capabilities of the units involved.

Equivalent scenarios were developed for diesel submarines. The first involved guerrilla attacks of the type attributed to Libya in the opening chapter. The scenario assumed a submarine transit to normal sea lanes and an attack in a situation most favorable to the submarine. No airborne ASW support was available.

The second submarine scenario was set in a war-at-sea situation. There was general agreement among the operators that the targets for the submarines would probably be enemy surface ships along the lines of Pakistani attacks in 1970, rather than enemy submarines. This is reasonable, given the complexities of submarine ASW, and the fact that few potential Third World conflicts involve two nations which both possess diesel submarines. In keeping with the Indo-Pakistani example, the scenario assumed that the surface unit was alert to the possibility of attack but

lacked airborne ASW support.

Other possible concerns entered into formulations of the questionnaire instructions. The basic concepts of utility theory and utility curves probably are new concepts for many judges. It was necessary to briefly describe the concepts. A curve was borrowed from the LeGrow study and was presented as an example accompanied by a brief interpretation. Discussions with various classmates demonstrated that the use of this example was an effective and concise method for acquainting the respondent with the concept of utility curves.

The interpretation which accompanied the curve defined the zero point as a "natural" origin--a necessary assumption for developing a ratio scale from MAUT.[80] The interpretation made it clear that a zero point was demanded of the judge and that a score of zero for a particular characteristic represented the absolute minimum value for that attribute which would allow successful accomplishment of the mission outlined in the scenario. "If the analyst is willing to generalize the validity of this point it can be considered a 'natural' origin and lead to ratio measurement."[81] This interpretation of the zero point was

emphasized in a number of contexts in each questionnaire.

Similar emphasis was placed on the upper limit of the utility curve. In theory the maximum utility value is one. However, most individuals consulted in the preliminary studies were more comfortable using whole numbers and a maximum of ten than they were using one as the upper limit. As a result, the scales in the questionnaires extended from a minimum of one to a maximum of ten. Since ratio measurement is being assumed, this enlargement is permissible. Ten was emphasized throughout the questionnaire as the value for an attribute which the judge considered technologically feasible/desirable.[82]

Tests of various questionnaire formats indicated that the precision of the curves and the accuracy of the judge's sketch could be improved by asking for his minimum and maximum utility points prior to asking him to sketch the curve for each attribute. This format was utilized in the final version of each questionnaire. This effort to promote accuracy had definite benefits when the results were aggregated (see Chapter V).

Finally, special efforts were taken to emphasize that

each judge was chosen because of his expertise and that the questionnaire sought subjective judgments based on that experience. It also was noted that each attribute should be considered to be independent of all others. The judge was directed to omit those characteristics which he did not feel qualified to evaluate.

The final step in the preparation process was to submit copies of the proposed questionnaire to three qualified judges at the Naval Postgraduate School who had not been consulted about the project previously. Two were given the questionnaire contained in Appendix B and one received the diesel submarine questionnaire in Appendix C. In each case the judge had no difficulty understanding what was expected of him. All aspects of the instructions were followed completely. The judges were in agreement that the questionnaires were extremely challenging and called for the judge to weigh very difficult trade-offs throughout. Each judge noted that it took 45 minutes to one hour to complete the questionnaire--a fact which seemed to threaten the desired high response rate. Because an all-inclusive measure of system military worth was more important to the research than a wide sample of judge's opinion, the questionnaires contained in Appendix B and C were submitted

to the prospective respondents without modification.

V. DEVELOPING SEA DENIAL CAPABILITY SCORES

This chapter presents the final five steps in the process of developing utility scores representing the sea denial capabilities of the antiship missile combatants and diesel submarines which have been transferred to Third World nations. It begins with the process involved in measuring the dimensions under study and traces the steps utilized to acquire platform capability scores. The final step in the chapter is the presentation of these utility scores to the decision maker.

A. STEP 6--MEASURE DIMENSIONS

The individual performance characteristics of antiship missile combatants and torpedo-firing diesel submarines found in Third World inventories constitute the dimensions to be evaluated. Measurement of these dimensions was involved in varying degrees at three points in the quantification of weapon system's military worth. A

preliminary examination was required in the questionnaire preparation phase outlined in Step 4. That investigation sought to identify dimensions which presented meaningful measures of system performance. The second inquiry formed part of Step 5. In Step 5 the investigation was aimed at developing an appreciation of the range among weapons with respect to particular dimensions in order to provide a realistic scale for the horizontal axis for each curve required of the judges in the questionnaires.

The in-depth examination of performance characteristics involved in Step 6 was a time-consuming process. However, the period of time between mailing and subsequent receipt of the questionnaires was sufficient to accomplish this analysis. Specific performance and inventory information was collected from various unclassified publications. Prominent sources were Aviation Week and Space Technology, Jane's Weapons Systems, Jane's Fighting Ships, Flight International, SIPRI publications and The World Military Balance.

Unexpected delays were encountered in two areas during the measurement process. In developing antiship missile platform inventory numbers the researcher encountered

difficulties in deciphering names of missile combatants found in various Third World nations' inventories. An example of the difficulties encountered is the fact that the Iranian SAAM-class is in reality the VOSPER MK-5, the Malaysian PERKASA FPB is produced as the BRAVE PTGL as is the Libyan SOUSA FPB. (These nomenclature difficulties are minimized in Appendix A by presenting the manufacturer's designations, rather than class names assigned by recipient nations to various types of antiship combatants.)

The second source of time delay was the extensive mix of weapons systems and combatant platforms; the individualized nature of supporting systems such as ECM/DECM and anti-missile defensive systems; and the wide variation in types of torpedoes capable of being fired by each class of submarine. To illustrate the individualized nature of various platforms, consider the fact that the LA COMBATTANTE II PTFG normally carries four EXOCET SSMs, but that the Malaysian version of the LA COMBATTANTE II carries two EXOCETs, Singapore's version mounts five GABRIEL SSMs, while Iran has ordered LA COMBATTANTE II PTFGs without missiles and may intend to mount HARPOON SSMs on these units.[83] This degree of diversity required that each be treated as a separate system, since diveristy in armament portends

possible differences in sea denial potential. This diversity greatly increased the effort devoted to the measurement phase of the research.

Measurement is also complicated by the fact that MAUT requires precise and complete information. Information about performance characteristics forms the basis for the valuation of military worth and must be complete to allow side-by-side comparisons of the military worth of various weapon systems. MAUT does not accomodate missing data. The absence of data for a particular dimension of one system requires that that characteristic be deleted for all systems in order to make side-by-side comparisons.

One deletion became necessary in the study of the military worth of antiship missile combatants. The preliminary research done in Steps 4 and 5 indicated that the necessary performance information was available to allow inclusion of "Maximum Radar Acquisition Range" in the questionnaire contained in Appendix B. The detailed examination done in Step 6 revealed that range information per se was not available for a number of radars mounted on Third World antiship missile combatants. Instead, radar information is often presented in the form of technical

characteristics such as pulse repetition rate, frequency, power, etc. The reason that the technical characteristics, rather than range information, are given may arise from the fact that radar ranges are extremely sensitive to atmospheric conditions. Factors, such as the ducting phenomenon fcund over-water in warm climates, can greatly alter radar acquisition ranges. The fact that this characteristic is variable and subject to conditions unrelated tc performance characteristics of a particular radar required that this dimension be deleted subsequent to mailing the questionnaires to the judges.

B. STEP 7--AGGREGATE UTILITY CURVES

Literature concerning multi-attribute utility analysis deals at length with problems involved in aggregating individual utilities into group utility functions. The discussion centers around theoretical constraints upon the manner in which individual utility curves can be combined.[84] Attention has also been devoted to the practical difficulties involved in aggregating utilities in a real-world decision-making situation.[85]

Edwards et al. reviewed the literature and concluded that averaging presented an acceptable method for resolving disagreement among judges.[86] There are two basic ways to average the curves received in the judges' questionnaire responses. Each will be discussed in turn. The curves for "Range at Maximum Sustained Speed" (Scenario #1) taken from Appendix D will serve as the basis for discussion in Steps 7, 8 and 9. These curves are reproduced in Figure 11.

One approach is to combine the individual curves into one agreed-upon utility curve for each dimension involved in the analysis. This might be accomplished through a Delphi instrument or might be accomplished by mathematically combining the individual curves provided by the judges. There are a number of problems with the Delphi technique which go beyond the scope of the present study. Disadvantages also accompany the mathematical combination approach.

The mathematical solution requires relatively involved manipulations which counter the goal of developing an application of MAUT which is easily explained to a decision maker. Presenting a single curve for each dimension also may be misleading to the extent that it conveys the

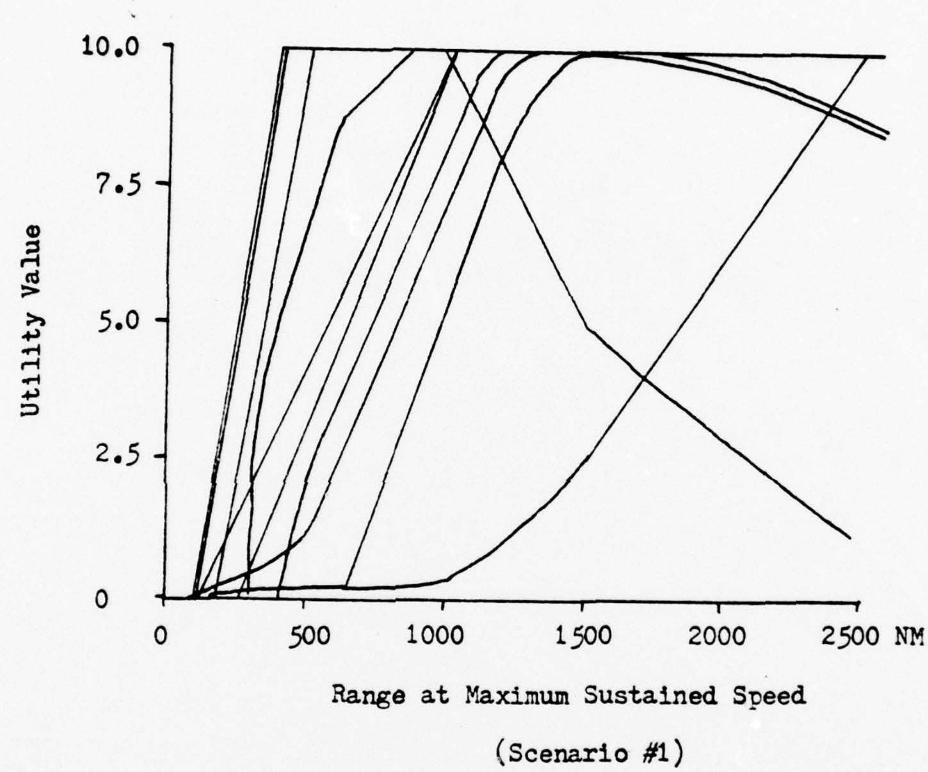


Figure 11 - CURVES FOR "RANGE AT MAXIMUM SUSTAINED SPEED"

impression that the judges reached a consensus when, in fact, a wide divergence of opinion with respect to a given dimension might exist. So, for example, the curve presented in Figure 12 for the dimension "Range at Maximum Sustained Speed" is much more visually appealing than the ten curves presented in Figure 11, but it does not display the degree of agreement/disagreement which existed among the judges. The mathematical complexities and the possible misrepresentation of consensus led to the adoption of a second method for aggregating utility values.

The second approach involves using the judges' utility curves directly to average the values for each dimension. So, for example, to determine the average utility value for a platform with a 1250 NM range at maximum sustained speed it would be necessary to take ten individual readings as shown in Figure 13. The values of the readings are summed (total value of 87 for this example) and this utility value is divided by the number of judges (10 in this case) to derive the average utility for this dimension for a platform with a 1250 NM range (8.7 in this example.)

The disadvantage inherent in this approach is obvious. Much more computational time is required than would have

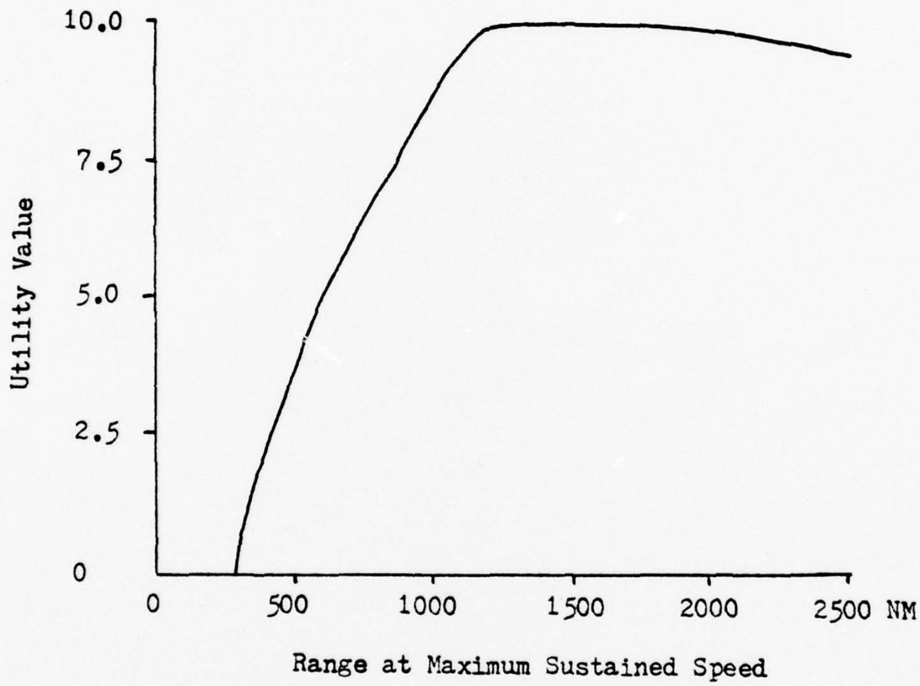


Figure 12 - COMBINED UTILITY CURVE

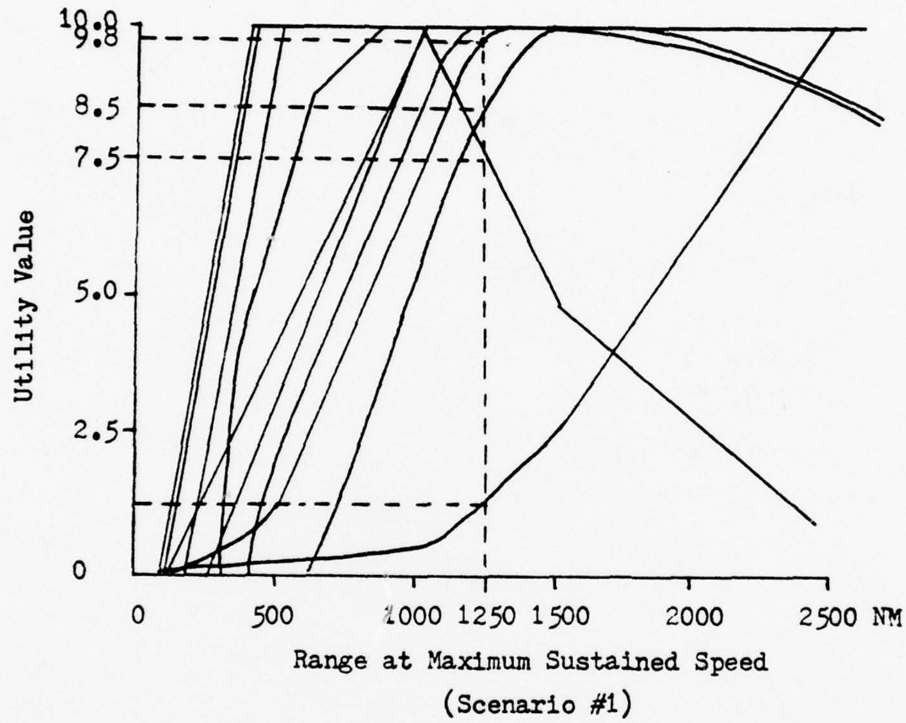


Figure 13 - UTILITY VALUES FOR 1250 NM RANGE

been the case if a combined curve had been used allowing the utility value to be read directly off the vertical axis. However, three advantages appear to out-weigh this drawback. First, the mathematics are easily understood and easily demonstrated. Second, the method avoids much of the theoretical discussion about the proper manner for developing group utility functions by going directly to the curves provided by the individual judges. Third, the method presents a visual representation of the variance in the judges' opinion. This advantage is very important because simple mathematical measures of variance and standard deviation are not applicable. A normal distribution has not been assumed. Moreover, the degree of variance depends upon the particular value for a dimension being studied. In the case of the dimension "Range at Maximum Sustained Speed" a visual inspection reveals that the variance in judges' opinions at the 1250 NM point is much less than the wide ranging judgments found at the 750 NM value. A visual representation of the degree of agreement/disagreement is vital to an unbiased presentation of the data in the absence of standard mathematical representations of variance. The decision maker should also be appraised of the fact that the degree of agreement/disagreement may vary among dimensions. A comparison of the curves presented in Figure 13, for

example, reveals far greater agreement than the curves for "Maximum Missile Range" (Scenario #2) shown in Figure 14.

Judges' curves for each dimension addressed in the antiship missile combatant questionnaire are contained in Appendix D. The curves for the dimensions included in the torpedo-firing diesel submarine questionnaire are displayed in Appendix E. Responses for the non-continuous variables presented in the respective questionnaires are also contained in the appropriate appendixes in tabular form. Twelve responses were received for the antiship missile combatant questionnaire (66 percent response rate) and six were received for the diesel submarine questionnaire (50 percent response rate). The fact that some judges did not evaluate various dimensions accounts for the variation in total numbers of responses among individual performance characteristics.

C. STEP 8--AGGREGATE IMPORTANCE WEIGHTINGS

Literature concerning applications for utility analysis devotes much space to the problem of properly weighting judgments. Kirkwood states that "...any practical

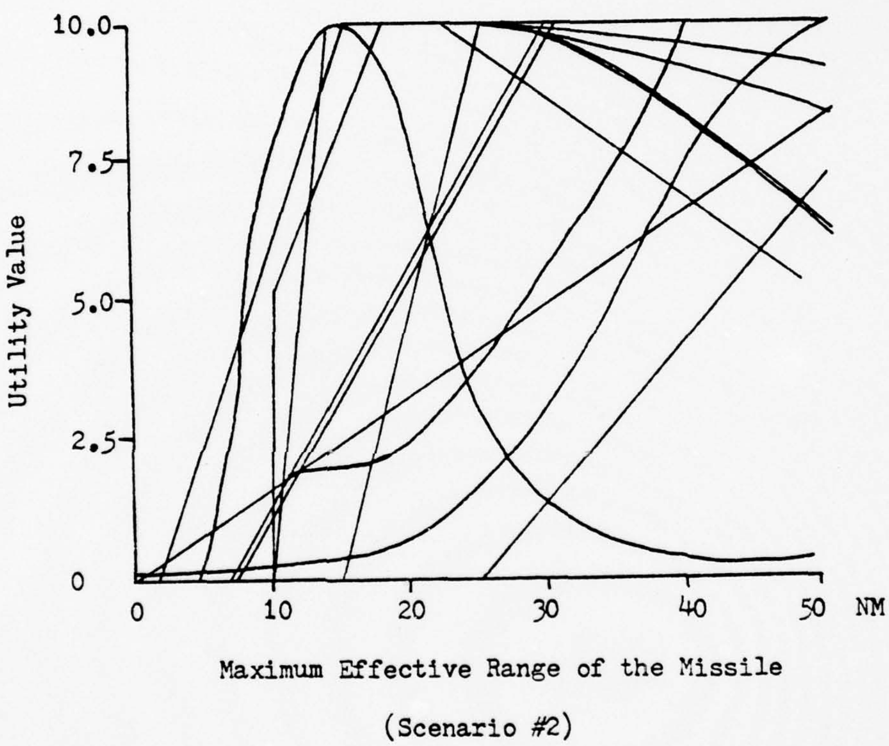


Figure 14 - UTILITY CURVES FOR "MAXIMUM MISSILE RANGE"

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QUANTITATIVE ASSESSMENT OF THIRD WORLD SEA DENIAL CAPABILITIES.(U)

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methodology should allow for an open display of the weight being given to different people's preferences."[87] Edwards et al. address the problem of properly weighting their dimensions.[88] The concern in their study was that judgments might be overstated/understated unless the judges assigned weightings to the dimensions to reflect the importance attached to each dimension. LeGrow expressed the same concern and asked the judges to provide weightings for aircraft performance characteristics along with the utility curves.[89] The weightings in the LeGrow study showed that some performance characteristics were more important to fighter aircraft capability than others.[90] The same situation was highly probable in an application of MAUT to sea denial capability.

In the sea denial study each judge was asked to weight each performance characteristic which he evaluated in the questionnaire. The individual weightings were averaged to develop overall weightings for each attribute. Table III presents the resultant average weightings for each of the performance characteristics contained in the antiship missile combatant questionnaire contained in Appendix E. Table IV presents the same information for the torpedo-firing diesel submarine questionnaire contained in

TABLE III

ANTISHIP MISSILE COMBATANT WEIGHTINGS

Scenario #1

Dimension	Judges' Weightings #1	#2	#3	#4	#5	#6	#7	#8	#9	Average Weighting	Standard Deviation
Designated Platform Speed	5	5	3	4	10	4	6	6	4	5.2	2.05
Platform Range at Maximum Sustained Speed	6	8	8	7		4	2	2	9	5.8	2.77
Standard Platform Displacement	4	2	7	3		4	4	4	2	3.8	1.58
Platform ECM Capabilities	3	2	1	4	7	4	8	8	1	4.2	2.82
Maximum Effective Range of Missile	5		9	10	8	7	6	6	4	6.1	2.19
Missile Speed	2		3	0		6	5	5	3	3.4	2.07
Warhead Size	5		1	9		8	5	5	6	5.6	2.58
Missile Hit Probability	5		1	8		10	6	6	9	6.4	2.99
Number of Missile Tubes	3		1	8		6	7	7	7	5.7	2.58
Type of Missile Guidance System	4		1	7	10	7	5	5	10	6.1	3.04
Home-on-Jam Capability	1		1	1	7	4	4	4	3	3.1	2.24
Fuzing Configuration	4		0	3		7	4	4	1	3.3	2.29

TABLE III (Cont.)

Scenario #2

Dimension	Judges' Weightings #1	#2	#3	#4	#5	#6	#7	#8	#9	Average Weighting	Standard Deviation
Designated Platform Speed	8	10	6	8	7	8	10	10	7	8.2	1.48
Platform Range at Maximum Sustained Speed	8	5	7	5		5	8	8	6	6.5	1.52
Standard Platform Displacement	3	8	6	7		6	4	4	2	5.0	2.07
Platform ECM Capabilities	7	7	4	8	9	7	8	8	5	7.0	1.58
Antiship Missile Defense Systems	8	10	3	7	10	7	6	6	6	7.0	2.00
Maximum Effective Range of Missile	8		8	6	8	9	5	5	7	7.0	1.51
Missile Speed	3		6	0		8	5	5	3	4.3	2.56
Warhead Size	4		3	7		8	5	5	3	5.0	1.91
Missile Hit Probability	6		5	10		10	8	8	9	8.0	0.91
Number of Missile Tubes	5		4	8		7	7	7	7	6.4	1.40
Type of Missile Guidance System	6		4	9	10	8	7	7	10	7.6	2.07
Home-on-Jam Capability	6		6	2	7	7	6	6	8	6.0	1.77
Fuzing Configuration	2		2	5		8	4	4	5	3.7	2.15

TABLE IV

TORPEDO-FIRING DIESEL SUBMARINE WEIGHTINGS

Scenario #1

Dimension	Judges' Weightings #1	#2	#3	#4	#5	#6	Average Weighting	Standard Deviation
Submerged Displacement	4	1	3	8	0	4	3.3	2.80
Submerged Speed	4	4	4	6	3	7	4.7	1.51
Submerged Endurance	6	3	9	5	4	2	4.8	2.48
Number cf Torpedo Tubes	7	2	1	10	2	2	4.0	3.63
Number cf Torpedoes	7	2	7	10	2	3	5.2	3.31
Torpedo Speed	8	4	8	8	6	4	6.3	1.97
Effective Range cf the Torpedo	8	3	8	8	5	5	6.2	2.14
Torpedo Guidance Systems	6	6	9	4	3	8	6.0	2.28
Acquisition Techniques	8	6	8	10	5	7	7.3	1.75
ESM Capability	6	5	5	4	8	4	5.3	1.51
SLAM Capability	8	10	1	0	1	3	3.8	4.17

TABLE IV (Cont.)

Scenario #2

Dimension	Judges' Weightings						Average Weighting	Standard Deviation
	#1	#2	#3	#4	#5	#6		
Submerged Displacement	5	1	3	6	0	2	2.8	2.31
Submerged Speed	5	9	6	10	3	3	6.0	2.97
Submerged Endurance	5	8	9	10	5	6	7.2	2.35
Number cf Torpedo Tubes	6	2	1	9	3	6	4.5	3.02
Number cf Torpedoes	6	2	6	9	2	7	5.3	2.80
Torpedo Speed	9	6	9	10	9	8	8.5	1.38
Effective Range cf the Torpedo	7	5	9	10	10	8	8.2	1.94
Torpedo Guidance Systems	9	7	9	10	9	9	8.8	0.98
Acquisition Techniques	8	6	8	10	5	8	7.5	1.76
ESM Capability	8	4	5	10	9	6	7.5	2.37
SLAM Capability	8	10	1	5	2	7	5.5	3.51

Appendix C. Once again some of the experts did not judge certain dimensions. This accounts for the divergence in numbers of responses.

The average weightings for the various dimensions are used to develop weighted utility scores. For the platform with the 1250 NM range the average utility score developed in Step 7 (8.7) is multiplied by the average weighting found under Scenario #1 in Table III. The resultant weighted attribute score for "Range at Maximum Sustained Speed" for this particular platform would be 50.

D. STEP 9--CALCULATE WEAPON SYSTEM UTILITIES

The result of the procedures contained in Step 7 and Step 8 is a series of weighted utility scores for dimensions of sea denial weapons systems. The purpose of Step 9 is to combine these weighted utilities to develop platform utility scores for antiship missile combatants and torpedo-firing diesel submarines.

The process to be followed in combining these weighted utility scores is determined by the presence or absence of

three properties within the utility functions. These three properties; utility independence, pairwise preferential independence, and pairwise marginality, are presented in some detail in the LeGrow thesis.[91] The presence or absence of these properties determines whether an additive or multiplicative combinatorial relationship exists. If the requirements for addition or multiplication are not present, or are not decipherable, most sources recommend the additive form as the best "...since it is generally a good approximation of the multi-attribute utility function."[92]

The diesel submarine and the missile combatant questionnaires explicitly noted interrelationships which exist between various performance characteristics the judge was asked to evaluate. The experts were involved in making difficult trade-offs throughout the evaluation process. Intertwining characteristics involved in these complex systems made the requirements for addition or multiplication indiscernable. Thus, the recommended additive form was adopted. Total utility scores for a particular weapon system were derived by summing the weighted utility scores derived in Steps 7 and 8.

Total utility scores for the antiship missile combatants

were greatly influenced by the performance characteristics of the missile systems mounted on these combatants. Seven of the thirteen dimensions ("Maximum Effective Range of the Missile", "Missile Speed", "Warhead Size", "Missile Hit Probability", "Missile Guidance Systems", "Home-on-Jam Capability" and "Fuzing Configuration") directly evaluate the performance of the missile. An eighth factor ("Number of Missile Tubes") is indirectly tied to missile characteristics such as size and weight. The MAUT technique permits a side-by-side comparison of system components such as the surface-to-surface missiles which have been transferred to various Third World recipients. The total utility scores were computed for the antiship missiles and are presented in Table V.

TABLE V

ANTISHIP MISSILE UTILITY SCORES

Scenario #1		Scenario #2	
OTOMAT	241	EXOCET	281
STYX	237	HARPOON	281
EXOCET	231	OTOMAT	273
HARPOON	226	STANDARD	271
STANDARD	181	STYX	252
GABRIEL I	149	GABRIEL I	213
SEAKILLER	126	SEAKILLER	164
SS-12	77	SS-12	56

Scores presented in Table V were derived by summing the weighted utility scores for the seven dimensions cited in the previous paragraph. The scores represent the maximum sea denial potential for each system. In each case the maximum range of the missile was used to calculate the system scores. The two systems with over-the-horizon capabilities were scored on the basis of their maximum effective ranges (37.5 NM for the OTOMAT[93] and in excess of 50 NM for the HARPOON[94]). The ducting phenomenon which can extend radar acquisition ranges over warm ocean areas and the concentration of Third World recipients in these areas makes over-the-horizon targeting possible in many situations. Range considerations had the opposite effect on the scores for the relatively short range (14 NM) GABRIEL SSM.[95] While the scores for the GABRIEL might appear to underestimate the military worth of this system, they are consistent with the evaluations of Israeli weapons designers who are involved in design and testing of the GABRIEL II SSM which has an expanded range (26 NM)[96] with improved guidance and higher speed.[97]

The missile system scores constitute part of antiship combatant scores displayed in Table VI and Table VII. These tables encompass all combinations of missiles and combatants found in Third World navies and those projected for the foreseeable future with the exception of the NANUCHKA which may be be delivered to India (see Appendix A).[98] The tables demonstrate the impact of the missile scores on overall platform scores. Technological considerations also play an important role in determining platform scores. The inclusion of ECM/DECM equipment and sophisticated antiship missile defense systems, such as the Gatling rapid-fire weapon, greatly influence the scores and relative rankings of the various platforms. The relative importance of speed and defensive capability in Scenario #2 is reflected in Table VII. In addition, the relatively higher scores in Scenario #2 show the impact of including a fourteenth characteristic ("Antiship Missile Defense Systems") to the evaluation.

Similar scores for torpedo-firing diesel submarines are provided in Table VIII. Contrary to the pattern encountered with the missile combatants, submarines of a particular class show little variation from recipient to recipient.

TABLE VI

ANTISHIP MISSILE COMBATANT UTILITY SCORES

Scenario #1

LA COMBATTANTE III PTFG (4 EXOCET)	377
DARING DDGS (8 EXOCET)	376
PR-72 PTFG (4 OTOMAT)	373
LUTA DDGS (6 STYX)	372
LUPO DDGS (4 OTOMAT)	371
GORDYY DDGS (4 STYX)	371
LA COMBATTANTE II PTFG (4 EXOCET)	368
LEANDER DEGSP (4 EXOCET)	368
FLETCHER DDGS (4 EXOCET)	364
36.2-METER PTG (2 EXOCET)	364
ALMIRANTE WILLIAMS DDGSP (4 EXOCET)	363
LA COMBATTANTE II PTFG (4 HARPOON)	363
PR-72 PTFG (4 EXOCET)	363
LURSEN 45-METER PTFG (4 EXOCET)	359
VOSPER MK-10 DDGSP (4 EXOCET)	356
U.S. PCEG (4 HARPOON)	355
SUMNER DDGS (4 EXOCET)	354
LUPO DDGS (2 OTOMAT)	352
LA COMBATTANTE II PTFG (2 EXOCET)	349
OSA I/II PTFG (4 STYX)	347
ASHVILLE PGG (2 HARPOON)	347
RIGA DEGS (2 STYX)	346
WHITBY DDGS (2 STYX)	346
FLETCHER DDGS (2 HARPOON)	340
VOSPER 37-METER PTFG (2 OTOMAT)	333

TABLE VI (Cont.)

SPRUANCE DDGS (2 HARPOON)	324
ASHVILLE PGG (4 STANDARD)	321
KOMAR PTG (2 STYX)	315
FLETCHER DDGS (4 STANDARD)	314
RESHEF/SAAR IV PTFG (8 GABRIEL)	308
BATTLE DDGSP (4 STANDARD)	307
SUMNER DDGS (4 STANDARD)	304
ASHVILLE PGG (2 STANDARD)	302
SAAR III PTG (6 GABRIEL)	297
GEARING DDGS (2 STANDARD)	295
RESHEF/SAAR IV PTFG (4 GABRIEL)	294
SAAR II PTG (5 GABRIEL)	292
LA COMBATTANTE II PTFG (5 GABRIEL)	291
LURSEN 45-METER PTFG (5 GABRIEL)	282
FLETCHER DDGS (4 GABRIEL)	282
SUMNER DDGS (4 GABRIEL)	272
LURSEN 45-METER PTFG (3 GABRIEL)	271
VOSPER MK-5 DDGS (4 SEAKILLER)	254
P-48 PGMGL (8 SS-12)	202
BRAVE PTGL (8 SS-12)	182

TABLE VII

ANTISHIP MISSILE COMBATANT UTILITY SCORES

Scenario #2

LA COMBATTANTE III PTFG (4 EXOCET)	502
LA COMBATTANTE II PTFG (4 EXOCET)	487
LA COMBATTANTE II PTFG (4 HARPOON)	487
ALMIRANTE WILLIAMS DDGSP (4 EXOCET)	479
LEANDER DEGSP (4 EXOCET)	475
LA COMBATTANTE II PTFG (2 EXOCET)	472
DARING DDGS (8 EXOCET)	468
FLETCHER DDGS (4 EXOCET)	461
LURSEN 45-METER PTFG (4 EXOCET)	459
LUPO DDGS (4 OTOMAT)	459
GEARING DDGS (2 STANDARD)	457
FLETCHER DDGS (4 STANDARD)	451
ASHVILLE PGG (4 STANDARD)	449
SUMNER DDGS (4 EXOCET)	447
PR-72 PTFG (4 EXOCET)	446
FLETCHER DDGS (2 HARPOON)	446
ASHVILLE PGG (2 HARPOON)	444
LUPO DDGS (2 OTOMAT)	444
U.S. PCEG (4 HARPOON)	443
RESHEF/SAAR IV PTFG (8 GABRIEL)	440
SAAR III PTFG (6 GABRIEL)	439
GORDYY DDGS (4 STYX)	439
BATTLE DDGSP (4 STANDARD)	439
PR-72 PTFG (4 OTOMAT)	438
SUMNER DDGS (4 STANDARD)	437

TABLE VII (Cont.)

SAAR II PTG (5 GABRIEL)	436
ASHVILLE PGG (2 STANDARD)	424
RESHEF/SAAR IV PTFG (4 GABRIEL)	424
LUTA DDGS (6 STYX)	424
LA COMBATTANTE II PTFG (5 GABRIEL)	421
36.2-METER PTG (2 EXOCET)	416
VOSPER MK-10 DDGS (4 EXOCET)	404
RIGA DEGS (2 STYX)	401
SPRUANCE DDGS (2 HARPOON)	400
OSA I/II PTFG (4 STYX)	396
VOSPER 37-METER PTFG (2 OTOMAT)	394
LURSEN 45-METER PTFG (5 GABRIEL)	393
FLETCHER DDGS (4 GABRIEL)	393
WHITEY DDGS (2 STYX)	389
LURSEN 45-METER PTFG (3 GABRIEL)	382
SUMNER DDGS (4 GABRIEL)	379
KOMAR PTG (2 STYX)	374
VOSPER MK-5 DDGS (4 SEAKILLER)	334
BRAVE PTGL (8 SS-12)	216
P-48 PGMGL (8 SS-12)	210

TABLE VIII

TORPEDO-FIRING DIESEL SUBMARINE UTILITY SCORES

Scenario #1		Scenario #2	
GUPPY III SS	412	TYPE 206/500 SS	484
TANG SS	410	TYPE 209 SS	478
GUPPY IA SS	407	GUPPY IA SS	442
GUPPY IIA SS	402	OBERON SS	440
HAN SS(N)	401	AGOSTA SS	439
GUPPY II SS	396	HAN SS(N)	435
FOXTROT SS	387	GUPPY II SS	426
TYPE 209 SS	386	TANG SS	425
GOLF SSB	375	FOXTROT SS	422
TYPE 206/500 SS	374	GUPPY IIA SS	421
AGOSTA SS	373	GUPPY III SS	417
OBERON SS	371	MING SS	415
MING SS	361	GOLF SSB	413
ROMEO SS	348	DAPHNE SS	400
DAPHNE SS	347	ROMEO SS	387
WHISKEY SS	331	WHISKEY SS	348
T-CONVERSION SS	326	T-CONVERSION SS	315
BALAO SS	284	BALAO SS	284
TIBURON SS	257	TIBURON SS	232

So, for example, a North Korean ROMEO SS is essentially the same as a Chinese (PRC) ROMEO or an Egyptian unit of the same class. The major exceptions to this rule come in two areas where the supplier retains a degree of control. One area of variation is in the electronics suit which is transferred along with the submarine. The second differentiation is in the types of torpedoes provided as part of the purchase package. For example, the West German decision to export wire-guided torpedoes with the TYPE 206 and TYPE 209 submarines plays a major role in determining the relatively high scores which these units received in Scenario #2. In like manner, the Soviets could greatly upgrade the sea denial scores for their exports, especially the FOXTROT SSs, by providing more sophisticated torpedoes to recipient nations.

Most of the submarines appearing in Table VIII have the capability to fire a variety of torpedoes. The submarine capability scores were developed by calculating the total utility scores for each of the torpedoes which have been transferred with each type of submarine (a combination of the scores for "Torpedo Speed", "Effective Range of the Torpedo", "Torpedo Guidance System") and selecting the torpedo with the highest score for inclusion in the total

score for that class of submarine. In cases where one torpedo had a higher score in one scenario and a second torpedo scored higher in the other scenario, the second torpedo would be used for the second scoring. So, for example, the French Z-16 torpedo was used to compute utility scores for the French AGOSTA SS in Scenario #1, while the E-12 scored highest for the AGOSTA SS in Scenario #2 and was used in making that calculation.

This method for determining maximum platform capability is consistent with an effort to portray the maximum sea denial capability of the platforms under consideration. It is also consistent with the assumption that the Third World military planner would load his submarines with the optimal torpedoes for the anticipated mission. The inclusion of the GOLF SSB is also consistent with an examination of maximum sea denial potential. While an antiship role is not the primary mission of an SSB, its 10 torpedo tubes do give it an antiship capability.[99] The PRC's single HAN SS(N) was included because it is still not certain whether the unit is diesel or nuclear powered.[100]

The submarine scores present an opportunity for comparing MAUT-derived scores to real-world circumstances.

The list encapsulates historical trends in submarine production for various submarine builders. The Soviets began production of the WHISKEY SS in 1951[101], switched to production of the ROMEO SS in 1958-61[102] and produced the FOXTROT SS beginning in 1958, but continued production until 1967 -- well after ROMEO production had ceased.[103] These production choices would be expected to reflect successive increases in the military worth of the diesel submarines being produced. The MAUT scores reflect an increasing sea denial capability for each successive class of submarine in both of the scenarios outlined in the questionnaire. The same holds true for the French transition from DAPHNE SS production to building the AGOSTA SS; the U.S. improvements going from the TIBURON SS to the BALAO SS to the GUPPY and TANG SSs; and the British shift from the T-CONVERSION SS to OBERON SS series production. The consistency of the results appears to demonstrate the usefulness of the MAUT technique and have the added advantage of quantifying apparent increases in military worth of various diesel submarines.

E. STEP 10--PRESENT SCORES TO DECISION MAKER

Most decision makers concerned with arms transfers and

sea denial threats are not acquainted with the concept of utility analysis. The use of MAUT-derived scores to assist the decision maker may require a brief explanation of the technique. The fact that the curves which form the basis for MAUT represent expert judgments should be emphasized. Presenting representative curves may be helpful in familiarizing the decision maker with the approach used in the preceeding nine steps. The scores contained in Tables V through VIII can be presented following a brief explanation.

In presenting MAUT analysis it may become necessary to caution against drawing unwarranted conclusions from the scores. One tendency is to attempt implicit combat modeling based on MAUT scores. It is very tempting to postulate from the scores for Scenario #2 that a Libyan PR-72 with EXOCET missiles should prevail over an Egyptian OSA PTFG in a one-on-one situation. However, MAUT scores cannot be used for combat modeling. Tendencies to misuse these utility scores must be countered with explanations that MAUT scores present rule-of-thumb indices of military worth which offer all of the advantages of quantification on a ratio scale, but that they do not predict combat outcomes.

Another tendency likely to be encountered is the desire

to focus on the ranking of various systems without noting the degree of difference between their scores. For instance, it is easy to sieze on the fact that the LA COMBATTANTE II PTFG/EXOCET SSM combination is ranked first in the Scenario #1 utility scores. The fact that the LEANDER DEGSP/EXOCET weapon system which ranks eighth scores only 2 percent below the LA COMBATTANTE II is important and must be brought out in the discussion. MAUT does not allow the precision necessary to make a differentiation which is as small as this. Instead, the first eight to ten units on the Scenario #1 list may be said to have approximately the same sea denial potential. At the same time, however, it can be said that the top group exhibits a significantly higher sea denial potential than those units which appear in the bottom half of the list.

The decision maker should also be cautioned against reading too much into scenario related/dependent scores. The utility values presented in the preceeding tables do not represent all-inclusive statements about the military worth of the weapons involved. A ship designed primarily for ASW which mounts a minimal antiship missile capability would be expected to score poorly in comparison with systems such as the LA COMBATTANTE II PTFG which were designed with the

missions outlined in the scenarios in mind. The scores say nothing about the overall military worth of the weapon systems being evaluated and the tendency to take the scores out of the context framed in the scenarios must be guarded against. The advantages of quantifying the threat discussed in the preceding chapters should be emphasized and the MAUT-derived scores should be offered as a tool which can assist in assessing the sea denial threat from lesser developed nations.

The platforms themselves offer a potential threat as demonstrated by the sea denial capabilities scores. However, one important factor remains to be considered. A problem often discussed with respect to the transfer of sophisticated weapons to Third World nations is the countries' ability/inability to effectively maintain and operate these systems. Clearly, if the recipients of the systems discussed thus far are unable to operate them effectively outside their home ports the potential sea denial capabilities will not be realized. The development of personnel scores and the computation of national sea denial capability scores is the subject of the following chapter.

VI. INCORPORATING HUMAN FACTORS

The military capabilities of lesser developed nations depend in large part on their ability to successfully employ advanced weapon systems. Questions concerning the ability to absorb the weapons, the adequacy of maintenance, the competence of the operators, the general technological skill level of the population, and the presence of foreign technicians and instructors become of prime importance. The questions are particularly applicable to the naval threat described in Chapters I and II. Systems which are not adequately maintained cannot put to sea. Antiship missile combatants lacking trained crews cannot effectively utilize the firepower inherent in the weapons platform. Maintenance and crew proficiency play an even greater role in submarine operations. Logistics and supply problems can further exacerbate difficulties which confront Third World navies.

The importance of personnel-related factors has long been recognized. These influences have traditionally been addressed in a rather general manner and are normally

presented as subjective assessments made by the analyst. Rattinger recognized the need to include personnel factors in his quantification scheme, but merely devised a very general measurement device.[104] LeGrow dealt with the problem by asking his judge to assign scores to various nations' capabilities to operate fighter aircraft. He incorporated these scores into his MAUT-derived capability scores.[105] LeGrow's methodology resulted in ratio-level scores which could be combined with platform utility scores to measure the air combat capabilities of various nations. However, his approach lacked the precision available with other judgmental techniques. It would also have been difficult to apply to scale a large number of instances such as the 37 nations which have acquired antiship missile combatants and/or torpedo-firing diesel submarines.

The difficulties prompted a search for an alternative scaling technique which could accomodate the relatively large number of cases involved in the study. The investigation of judgmental scaling methods was further constrained by the requirement that the technique provide ratio-level information which could be mathematically combined with platform utility scores. The Constant Sum Method meets these requirements. The Constant Sum Method is

a well established scaling technique which dates back to the 1930's. It was improved and modified in the period leading up to the publication of Torgerson's _Theory and Methods of Scaling_ in 1958.[106]

The method calls upon the judge to consider every possible pair of instances. Within each pair the judge is asked to divide 100 points between the two instances "...in accordance with the absolute ratio of the greater to the lesser."[107] For example, a 50-50 split would indicate a judgment that the two instances were of equal magnitude, while an 80-20 division would indicate that the former was four times as large as the latter. The judge is called upon to evaluate n(n-1)/2 pairs of instances if there are n instances to scale. So, for the 37 nations possessing antiship missile combatants and/or diesel submarines, the judge would have to evaluate 666 pairs of instances. (This was an obvious area of concern which will be addressed in the next section.) Internal inconsistencies which might occur within this large group of judgments are minimized by applying a least-squares fit to the data received from the judges. (An in-depth example of the constant sum methodology with accompanying discussion is presented in Torgerson.)[108] The Constant Sum methodology provides

ratio-level data. It also is capable of measuring the personnel factors which influence military capabilities of the relatively large number of nations included in the present study. What is more important, however, is the fact that it permiits a greater degree of precision than the LeGrow approach and combines the judgments of numerous experts into a single capability scale. These advantages led to the adoption of the Constant Sum technique to scale Third World personnel factors related to sea denial capabilities.

A. QUESTIONNAIRE PREPARATION

The requirement to bring together judges with wide-ranging knowledge of the capabilities of Third World navies dictated that evaluations be solicited through questionnaires. In an era of specialization, with the attendant tendency for analysts to concentrate on narrowly defined geographic areas, this general expertise is unusual. The problem is compounded when the broad expertise must be coupled with the in-depth knowledge necessary for meaningful evaluation of specific Third World navies.

Twenty judges eventually were selected. All were personally known to the researcher. The judges ranged in rank from Lieutenant to Commander. Each has had extensive staff-level experience as a naval analyst. Five had recent experience as members of U.S. Navy fleet staffs. This experience carried with it an in-depth appreciation for the capabilities of navies found within the geographic area in which their fleet operated.

The questionnaire which was developed (Appendix F) asked the judge to evaluate Third World nations' capabilities to successfully operate antiship missile combatants and/or torpedo-firing diesel submarines in an open ocean sea denial mission. The instructions suggested that evaluations might be based in part on a demonstrated capability to perform the open ocean mission, the presence of the technology and training necessary for successful accomplishment of the mission, and the ability of a particular nation to man the platforms with competent crews. The purpose of the suggestions was to focus the judge's attention on an evaluation of the personnel factors, as opposed to the performance characteristics of the platforms found in the various naval inventories. The judges' instructions concluded with a brief explanation of the Constant Sum

scaling technique and an example accompanied by an interpretation of the hypothetical results.

The questionnaire was divided into three separate country lists. Each encompassed a specific geographic region. This breakdown sought to exploit the expertise of those judges assigned to the fleet staffs by tailoring a portion of the questionnaire to fit their operational expertise in specific geographic areas. The three lists were linked by including India on Country List #1 and #2 and by including Israel on Country List #1 and #3.

Sixteen of the twenty questionnaires were returned (80 percent response rate). The majority of the judges responded to more than one portion of the questionnaire. This indicates that the researcher's concern over the length of the questionnaire and the fact that the judge was being asked to evaluate a large number of pairs of instances was largely unfounded.

B. COMPUTE COUNTRY CAPABILITY SCORES

The actual computations used to derive country

capability scores represent a refinement of the Torgerson treatment of the Constant Sum Method.[109] The computations will be demonstrated in the following paragraphs by using actual judges' scores for various Middle Eastern nations taken from Country List #1. The example is based upon the scores assigned to Egypt and Israel by the sixteen judges who evaluated their relative naval capabilities. The judges' scores for these two nations are displayed in Table IX. The first step consists of averaging judges' responses for each nation involved in the study. The average score for Egypt with respect to Israel is 505 divided by 16 or 31.5625 and the average score for Israel is 1095 divided by 16 or 68.4375.

The second step in the computations involves placing these average scores on an array displayed in part in Table X. The array for Country List #1 would have 13 rows and 13 columns corresponding to the 13 nations included in the list. (The averages for Iran and Iraq have been included in Table X to increase the completeness of the example.) Scores for particular nations are arrayed to be read down the columns. Thus, the average score for Egypt compared to Iran is 44.6875, Egypt compared to Iraq 70.3125, Egypt compared to Israel 31.5625, etc.

TABLE IX

JUDGES' CAPABILITY SCORES FOR EGYPT AND ISRAEL

	Egypt	Israel		Egypt	Israel
Judge #1	35	65	Judge # 9	40	60
Judge #2	35	65	Judge #10	40	60
Judge #3	30	70	Judge #11	35	65
Judge #4	40	60	Judge #12	20	80
Judge #5	30	70	Judge #13	30	70
Judge #6	20	80	Judge #14	50	50
Judge #7	20	80	Judge #15	20	80
Judge #8	40	60	Judge #16	20	80

TABLE X

ARRAY OF AVERAGE CAPABILITY SCORES

	Egypt	Iran	Iraq	Israel	....
Egypt	50.0000	55.3125	29.6875	68.4375	....
Iran	44.6875	50.0000	29.0625	61.8750	....
Iraq	70.3125	70.9375	50.0000	78.7500	....
Israel	31.5625	38.1250	21.2500	50.0000	....
......	....	....	....	....	....
......	....	....	....	....	....
......	....	....	....	....	....

Step 3 involves constructing a second array displaying the ratios of the values for pairs of nations. Thus, the score for Egypt with respect to Iran is 44.6875 divided by its counterpart across the diagonal depicted in Table XI (55.3125) to give a score of .80791. The score for Iran with respect to Egypt is the reciprical of .80791 or 1.23776. In like manner the score for Egypt compared to Iraq is 36842 divided by .42222 or 5.60945. The reciprocal (.17827) gives the score for Iraq with respect to Egypt. The same computations are completed for each pair across the diagonal of the array. The resultant array is found in Table XI. Again, the total array would have 13 rows and 13 columns.

TABLE XI

ARRAY OF RATIO SCORES

	Egypt	Iran	Iraq	Israel	.....
Egypt	1.0000	1.2378	0.4222	2.1683	......
Iran	0.8079	1.0000	0.4096	1.6229	......
Iraq	2.3684	2.4409	1.0000	3.7059	......
Israel	0.4612	0.6162	0.2698	1.0000	......
......	......	......	......	......	......
......	......	......	......	......	......

The final step is to take the geometric mean of the columns. Thus, the score for Egypt would be determined by the product of (1)(.80791)(2.36842)(.46119)....=10950.1948 taken to the 1/13 power since there are 13 entries in the column. The resultant scale value for Egypt is 2.04515. Similar geometric means taken for each column in turn determine the scale values for each nation. The scale values for each of the three country lists are shown in Table XII. By using the overlapping scores for India and Israel it is possible to combine the scores into one scale. The combined scale is displayed in Table XIII.

C. COMBINING PLATFORM AND PERSONNEL-RELATED SCORES

Both the antiship missile combatant and the diesel submarine questionnaires (Appendix B and C) asked the judges to evaluate the relative importance of personnel and platform-related factors to mission success. In each case the scores were placed on a scale ranging from a minimum of zero to a maximum of ten. A ratio-level scale was achieved by defining zero as a natural origin --- the point at which a factor makes no contribution to performance of the mission

TABLE XII

RAW PERSONNEL-RELATED FACTOR SCORES

COUNTRY	FACTOR SCORES		
	List #1	List #2	List #3
Country List #1			
Egypt	2.0452		
Iran	2.3764		
Iraq	0.9757		
Israel	3.3387		2.9072
Saudi Arabia	0.8431		
Pakistan	1.0065		
India	1.9308	1.7229	
Algeria	0.6405		
Libya	0.6822		
Morocco	0.5350		
Tunisia	0.4672		
Ivory Coast	0.2537		
Syria	1.3913		
Country List #2			
South Africa		1.8399	
Brunei		0.3000	
China (PRC)		2.2885	
Indonesia		0.8899	
Korea (North)		1.5699	
Korea (South)		1.2445	
Malaysia		0.6435	
Singapore		0.7387	
Taiwan		1.2306	
Thailand		0.6570	
Vietnam		0.6876	
Country List #3			
Argentina			1.2048
Brazil			1.1660
Chile			0.9137
Columbia			0.6429
Cuba			1.3035
Ecuador			0.5315
Peru			0.7878
Uruguay			0.5170
Venezuela			0.7311
Greece			1.3755
Turkey			1.4691

TABLE XIII

PERSONNEL-RELATED FACTOR SCORES

Country	Score	Country	Score
Israel	3.34	Iraq	0.98
China (PRC)	2.56	Peru	0.90
Iran	2.38	Saudi Arabia	0.84
South Africa	2.06	Venezuela	0.84
Egypt	2.05	Singapore	0.83
India	1.93	Vietnam	0.77
Korea (North)	1.76	Columbia	0.74
Turkey	1.69	Thailand	0.74
Greece	1.58	Malaysia	0.72
Cuba	1.50	Libya	0.68
Korea (South)	1.39	Algeria	0.64
Syria	1.39	Ecuador	0.61
Argentina	1.38	Uruguay	0.59
Taiwan	1.38	Morocco	0.53
Brazil	1.34	Tunisia	0.47
Chile	1.05	Brunei	0.34
Pakistan	1.01	Ivory Coast	0.25
Indonesia	1.00		

Note: The questionnaire failed to include Somalia and Senegal. Both have close counterparts in terms of geographic proximity, similarity of equipment and supplier, and date of initial equipment acquisition. Based on these considerations, Senegal has been assigned Ivory Coast's score of 0.25 and Somalia has been assigned Iraq's score of 0.98 for use in future computations.

outlined in the scenario. The scores received from the individual judges are displayed in Table XIV along with the average scores for the factors and the standard deviations for each. Only seven of the antiship missile combatant judges chose to provide weighting scores, while all of the submarine questionnaire respondents provided weightings.

The judges' replies confirmed the importance of personnel-related factors in evaluating sea denial capabilities of lesser developed nations. There was substantial agreement that personnel-related factors were more important than platform performance characteristics in the case of the missile combatants. In the case of the diesel submarines, the factors were judged to be roughly equivalent. In both cases the relative importance of the personnel-related considerations increased in the Scenario #2 combat situation. The clear implication is that any assessment of Third World sea denial capabilities which excludes an evaluation of personnel-related considerations fails to include an extremely important determinant of the threat.

The personnel and platform weightings provided by the experts must be included in the evaluation of the sea denial

TABLE XIV

HUMAN AND PLATFORM PERFORMANCE WEIGHTINGS

Antiship Missile Combatants (Scenario #1)

Factor	Judges' Scores									Average Score	Standard Deviation
	#1	#2	#3	#4	#5	#6	#7	#8	#9		
Human Performance	8			6	10	8	10	10	10	8.9	1.57
Platform Performance	7			8	10	8	8	8	7	8.0	1.00

Antiship Missile Combatants (Scenario #2)

Factor	#1	#2	#3	#4	#5	#6	#7	#8	#9	Average Score	Standard Deviation
Human Performance	10			8	10	10	10	10	10	9.7	0.76
Platform Performance	9			7	10	10	8	8	9	8.7	1.11

Torpedo-Firing Submarines (Scenario #1)

Factor	Judges' Scores						Average Score	Standard Deviation
	#1	#2	#3	#4	#5	#6		
Human Performance	8	6	9	10	9	5	7.8	1.94
Platform Performance	8	6	9	10	8	9	8.3	1.37

Torpedo-Firing Submarines (Scenario #2)

Factor	#1	#2	#3	#4	#5	#6	Average Score	Standard Deviation
Human Performance	9	8	9	10	10	8	9.0	0.89
Platform Performance	8	8	9	10	9	9	8.8	0.69

potential of a specific nation's naval inventory. In order for the weightings to be applied in concert with the platform and personnel scores, the scales had to be transformed. Transformation of the scales for antiship missile combatants (Tables VI and VII), diesel submarines (Table VIII) and personnel-related factors (Table XIII) was necessary in part because the scales were based on differing numbers of performance characteristics. Twelve factors were included in the antiship missile combatant scores for Scenario #1. Thirteen characteristics went into the calculations of the antiship missile combatant scores for Scenario #2. Eleven totally different characteristics formed the basis for computations of utility scores for the diesel submarines. The personnel-related factors obviously were computed on a different base.

Transformation of ratio-level data is permitted so long as the transformation coefficient is greater than zero and the transformation takes the form of b(x), where b is the coefficient and (x) is the existing scale value.[110] The coefficients used in the current transformations were selected so that the value for the platform with the highest score on each scale would equal twenty. The transformation of the utility score for the antiship missile combatants

TABLE XV

TRANSFORMED ANTISHIP MISSILE COMBATANT

UTILITY SCORES

Scenario #1

LA COMBATTANTE III PTFG (4 EXOCET)	20.00
DARING DDGS (8 EXOCET)	19.95
PR-72 PTFG (4 OTOMAT)	19.79
LUTA DDGS (6 STYX)	19.73
LUPO DDGS (4 OTOMAT)	19.68
GORDYY DDGS (4 STYX)	19.68
LA COMBATTANTE II PTFG (4 EXOCET)	19.52
LEANDER DDGSP (4 EXOCET)	19.52
FLETCHER DDGS (4 EXOCET)	19.31
36.2-METER PTG (2 EXOCET)	19.31
ALMIRANTE WILLIAMS DDGSP (4 EXOCET)	19.26
LA COMBATTANTE II PTFG (4 HARPOON)	19.26
PR-72 PTFG (4 EXOCET)	19.26
LURSEN 45-METER PTFG (4 EXOCET)	19.05
VOSPER MK-10 DDGSP (4 EXOCET)	18.89
U.S. PCEG (4 HARPOON)	18.83
SUMNER DDGS (4 EXOCET)	18.78
LUPO DDGS (2 OTOMAT)	18.67
LA COMBATTANTE II PTFG (2 EXOCET)	18.51
OSA I/II PTFG (4 STYX)	18.41
ASHVILLE PGG (2 HARPOON)	18.41
RIGA DEGS (2 STYX)	18.36
WHITBY DDGS (2 STYX)	18.36
FLETCHER DDGS (2 HARPOON)	18.04
VOSPER 37-METER PTFG (2 OTOMAT)	17.67

TABLE XV (Cont.)

SPRUANCE DDGS (2 HARPOON)	17.19
ASHVILLE PGG (4 STANDARD)	17.03
KOMAR PTG (2 STYX)	16.71
FLETCHER DDGS (4 STANDARD)	16.66
RESHEF/SAAR IV PTFG (8 GABRIEL)	16.34
BATTLE DDGSP (4 STANDARD)	16.29
SUMNER DDGS (4 STANDARD)	16.13
ASHVILLE PGG (2 STANDARD)	16.02
SAAR III PTG (6 GABRIEL)	15.76
GEARING DDGS (2 STANDARD)	15.65
RESHEF/SAAR IV PTFG (4 GABRIEL)	15.60
SAAR II PTG (5 GABRIEL)	15.49
LA COMBATTANTE II PTFG (5 GABRIEL)	15.44
LURSEN 45-METER PTFG (5 GABRIEL)	14.96
FLETCHER DDGS (4 GABRIEL)	14.96
SUMNER DDGS (4 GABRIEL)	14.43
LURSEN 45-METER PTFG (3 GABRIEL)	14.38
VOSPER MK-5 DDGS (4 SEAKILLER)	13.47
P-48 PGMGL (8 SS-12)	10.72
BRAVE PTGL (8 SS-12)	9.66

TABLE XVI

TRANSFORMED ANTISHIP MISSILE COMBATANT

UTILITY SCORES

Scenario #2

LA COMBATTANTE III PTFG (4 EXOCET)	20.00
LA COMBATTANTE II PTFG (4 EXOCET)	19.40
LA COMBATTANTE II PTFG (4 HARPOON)	19.40
ALMIRANTE WILLIAMS DDGSP (4 EXOCET)	19.08
LEANDER DEGSP (4 EXOCET)	18.92
LA COMBATTANTE II PTFG (2 EXOCET)	18.80
DARING DDGS (8 EXOCET)	18.65
FLETCHER DDGS (4 EXOCET)	18.37
LURSEN 45-METER PTFG (4 EXOCET)	18.29
LUPO DDGS (4 OTOMAT)	18.29
GEARING DDGS (2 STANDARD)	18.21
FLETCHER DDGS (4 STANDARD)	17.97
ASHVILLE PGG (4 STANDARD)	17.89
SUMNER DDGS (4 EXOCET)	17.81
PR-72 PTFG (4 EXOCET)	17.77
FLETCHER DDGS (2 HARPOON)	17.77
ASHVILLE PGG (2 HARPOON)	17.69
LUPO DDGS (2 OTOMAT)	17.69
U.S. PCEG (4 HARPOON)	17.65
RESHEF/SAAR IV PTFG (8 GABRIEL)	17.53
SAAR III PTFG (6 GABRIEL)	17.49
GORDYY DDGS (4 STYX)	17.49
BATTLE DDGSP (4 STANDARD)	17.49
PR-72 PTFG (4 OTOMAT)	17.45

TABLE XVI (Cont.)

SUMNER DDGS (4 STANDARD)	17.41
SAAR II PTG (5 GABRIEL)	17.37
ASHVILLE PGG (2 STANDARD)	16.89
RESHEF/SAAR IV PTFG (4 GABRIEL)	16.89
LUTA DDGS (6 STYX)	16.89
LA CCMBATTANTE II PTFG (5 GABRIEL)	16.77
36.2-METER PTG (2 EXOCET)	16.57
VOSPER MK-10 DDGS (4 EXOCET)	16.10
RIGA DEGS (2 STYX)	15.98
SPRUANCE DDGS (2 HARPOON)	15.94
OSA I/II PTFG (4 STYX)	15.78
VOSPER 37-METER PTFG (2 OTOMAT)	15.70
LURSEN 45-METER PTFG (5 GABRIEL)	15.66
FLETCHER DDGS (4 GABRIEL)	15.66
WHITBY DDGS (2 STYX)	15.50
LURSEN 45-METER PTFG (3 GABRIEL)	15.22
SUMNER DDGS (4 GABRIEL)	15.10
KOMAR PTG (2 STYX)	14.90
VOSPER MK-5 DDGS (4 SEAKILLER)	13.31
BRAVE PTGL (8 SS-12)	8.61
P-48 PGMGL (8 SS-12)	8.37

TABLE XVII

TRANSFORMED TORPED-FIRING DIESEL SUBMARINE UTILITY SCORES

Scenario #1		Scenario #2	
GUPPY III SS	20.00	TYPE 206/500 SS	20.00
TANG SS	16.33	TYPE 209 SS	19.75
GUPPY IA SS	16.22	GUPPY IA SS	18.26
GUPPY IIA SS	16.02	OBERON SS	18.18
HAN SS(N)	15.98	AGOSTA SS	18.14
GUPPY II SS	15.78	HAN SS(N)	17.98
FOXTROT SS	15.42	GUPPY II SS	17.60
TYPE 209 SS	15.38	TANG SS	17.56
GOLF SSB	14.94	FOXTROT SS	17.44
TYPE 206/500 SS	14.90	GUPPY IIA SS	17.40
AGOSTA SS	14.86	GUPPY III SS	17.23
OBERON SS	14.78	MING SS	17.15
MING SS	14.38	GOLF SSB	17.07
ROMEO SS	13.86	DAPHNE SS	16.53
DAPHNE SS	13.82	ROMEO SS	15.99
WHISKEY SS	13.19	WHISKEY SS	14.38
T-CONVERSION SS	12.99	T-CONVERSION SS	13.02
BALAO SS	11.31	BALAO SS	11.74
TIBURON SS	10.24	TIBURON SS	9.59

TABLE XVIII

TRANSFORMED PERSONNEL-RELATED FACTOR SCORES

Country	Score	Country	Score
Israel	20.00	Iraq	5.87
China (PRC)	15.34	Peru	5.39
Iran	14.26	Saudi Arabia	5.03
South Africa	12.34	Venezuela	5.03
Egypt	12.28	Singapore	4.97
India	11.56	Vietnam	4.61
Korea (North)	10.54	Columbia	4.43
Turkey	10.06	Thailand	4.43
Greece	9.46	Malaysia	4.31
Cuba	8.99	Libya	4.07
Korea (South)	8.33	Algeria	3.83
Syria	8.33	Ecuador	3.65
Argentina	8.27	Uruguay	3.53
Taiwan	8.27	Morocco	3.17
Brazil	8.03	Tunisia	2.82
Chile	6.29	Brunei	2.04
Pakistan	6.05	Ivory Coast	1.50
Indonesia	6.05		

contained in Table VI, for example, required that the previous utility values be multiplied by a transformation coefficient of .053 to convert the score for the LA COMBATTANTE III PTFG from 377 to 20. Each score on the same scale was subsequently multiplied by the same coefficient to complete the transformation and develop the scale displayed in Table XV.

It is worth noting that this transformation does not affect the natural origin and does not alter the relationship between the scores for combatants measured on the scale A simple example will prove this point. In Table VI the scores ranged from the LA COMBATTANTE III PTFG's 377 to the BRAVE PTGL's 182. On the transformed scale the respective utility scores were 20.00 and 9.66. On both scales the score for BRAVE PTGL was equal to 48 percent of the score for the LA COMBATTANTE III. The relationships between the scores for other ships on the same scale were similarly unaffected.

Similar transformations with the appropriate coefficients were accomplished for the scales contained in Tables XVI, XVII and XVIII. In each case the transformation coefficient was arbitrarily selected to set the platform/

country with the highest score equal to twenty.

Platform utility scores and personnel-related factors were examined for utility independence, pairwise preferential independence and pairwise marginality to determine the correct combinatorial relationship. The same concepts and rules apply which pertained to determining the correct relationship for calculating platform utility in Step 9. The questionnaires were constructed so as to treat platform utility independent of personnel factors. The country factor scores were similarly separated from considerations of weapon system sophistication and capability. The two independence tests and the choice indifference situation addressed in pairwise marginality are all present. The additive combinatorial relationship applies when all three tests are met.[111] The score for a sea denial platform in a particular nation's inventory was determined by multiplying the factor weighting found in Table XIV times the personnel factor score for that particular country (Table XVIII). The platform factor weighting from Table XIV was similarly multiplied by the appropriate transformed utility score. The two resultant figures were summed to determine the sea denial score for the particular platform.

An example comparing three specific platforms will display the procedure used to develop platform scores and will compare demonstrated Third World capabilities with scores derived through the technique just described. Many observers might feel that the scores displayed in Table XVI do not reflect the mastery the Israeli RESHEF/SAAR IV PTFG displayed during the October 1973 war. As demonstrated in the previous section of this chapter, platform utility scores only present one determinant of military capability. Personnel-related factors play a major part in determining the effectiveness of naval platforms. Israel is generally recognized to have well-trained military personnel and the capability to utilize and maintain military equipment. This ability is reflected in the high personnel factor score assigned to Israel by the experts. Examining the platform utility scores in isolation is misleading. A side-by-side comparison of the Israeli RESHEF/SAAR IV and the OSA I PTFGs of Israel's opponents set in the Scenario #2 war-at-sea situation which include the personnel factor may be more revealing.

a. Israeli RESHEF/SAAR IV PTFG:

$$(9.7)(20.00) + (8.7)(17.53) = 347$$

b. Egyptian OSA I PTFG:

$$(9.7)(12.28) + (8.7)(15.78) = 256$$

c. Syrian OSA I PTFG:

$$(9.7)(8.33) + (8.7)(15.78) = 218$$

The scores show the Israeli RESHEF/SAAR IV to be 1.35 times as effective within the war-at-sea scenario as the Egyptian OSA PTFG and approximately 1.6 times as effective as the Syrian OSA. While this is a static measure which does not allow combat modeling or predicting outcomes of specific engagements, it does appear to reflect the previously demonstrated capabilities of the individual nations.

As was the case with the submarine utility scores examined in Chapter V, quantification which corresponds to subjective judgments of decision makers and analysts who deal with the problem is essential to achieving their acceptance of the measurement technique. Comparison of MAUT-derived capability scores with the demonstrated abilities of specific nations to successfully employ the weapon systems is a highly visible test of validity. Unfortunately, there are few instances where Third World nations have demonstrated sea denial/interdiction capabilities. Thus, it is extremely important for the MAUT technique to meet the few validity checks which are available. In the case of the submarine developments enunciated in Chapter V and the brief assessment of the

Arab-Israeli comparison MAUT has met the validity test.

D. DEVELOPING NATIONAL SEA DENIAL INDEXES

Combining sea denial capability scores for antiship missile combatants and diesel submarines involves comparing "apples and oranges" to the extent that dissimilar systems are involved. However, there is a common threat posed by the two types of systems which promotes their combination into a common index. CDR Eldridge dealt with the problem of combining firepower indexes by multiplying submarine firepower scores by a factor of 1.2 before combining submarine scores with the scores for the antiship missile combatants. The 1.2 factor was an intuitive score designed "...to account for the increased complexity of the... defensive problem"[112] presented by submerged platforms.

Gathering expert opinion about the weighting to apply to either the submarine or the missile combatant threat presents an alternative to simple intuitive reasoning. Ten U.S. Navy Surface Warfare Officers at the Naval Postgraduate School were asked to place themselves in the position of the Captain of the merchant ship/tanker or Commanding Officer of

the surface combatants under attack in the scenarios outlined in the sea denial questionnaires (Appendix B and C). Each was asked to assign a value ranging from zero to ten to the threat posed by an antiship missile combatant or a diesel submarine in each scenario. Again zero was defined as the point at which the attacker posed no threat. The average score assigned to both the missile combatant and the diesel submarine in the Scenario #1 attack upon a merchant ship/tanker was 8.6. When placed in the position of the Commanding Officer of the surface combatant in the Scenario #2 combat situations, the judges assigned a score of 6.3 to the typical missile ship and an average score of 5.8 to the diesel submarine threat. The fact that the experts evaluated the two threats as being of approximately equal magnitude removed the requirement to weight either factor in developing overall capability scores. (No attempt will be made to compare capability scores from Scenario #1 to Scenario #2.)

The development of aggregate sea denial capability scores for each of the Third World nations demonstrates the flexibility inherent in MAUT-derived judgments of military worth. It also presents information which might be requested by a decision maker. It provides a meaningful

index of the naval balance within a particular geographical area. It also would assist a policy maker faced with the difficult decisions which accompany requests for security assistance to meet a perceived threat from a neighboring nation. A number of additional uses for such an index might be envisioned. Suffice it to say that an index of this type is in keeping with the demands which might be placed on a researcher by a decision maker.

An overall sea denial/interdiction score requires an up-to-date naval order-of-battle listing such as the one contained in Appendix A. Utility scores for a particular weapon platform are combined with the personnel-related factor score as demonstrated in the previous section of this chapter. The resultant score is multiplied by the number of platforms of that type contained in the nation's naval inventory. Scores for particular types of weapon systems are summed to develop aggregate sea denial scores for each nation in turn. (Table XIX presents the scores for Scenario #1 and Table XX displays similar scores for Scenario #2.)

The two tables present the decision maker with a large amount of information about the sea denial/interdiction capabilities of Third World nations. Each shows the current

TABLE XIX

NATIONAL SEA DENIAL CAPABILITY SCORES

Scenario #1

Country	Missile Combatant Score	Diesel Submarine Score	Total (1976) Score	Future (1980) Score
<u>Eastern Mediterranean</u>:				
Greece	1938	1252	3190	3794
Turkey	250+	2939	3189+	4428+
<u>Central and South America</u>:				
Argentina	0	778	778	2818+
Brazil	0	1610	1610	2426
Chile	844	343	1187	1187
Columbia	0	324	324	324
Cuba	4982	0	4982	4982*
Ecuador	555	0	555	867
Peru	415	1200	1615	2743
Uruguay	0	0	0	310
Venezuela	640	558	1198	2578
<u>North Africa and Middle East</u>:				
Algeria	1551	0	1551	1551
Egypt	4212	2783	6995	6995
Iran	1707	0	1707	6877
Iraq	1995	0	1995	1995*
Israel	5491	264	5755	8446
Libya	341	160	501	7607
Morocco	182	0	182	1776
Saudi Arabia	0	0	0	0+
Syria	2576	0	2576	2576*
Tunisia	333	0	333	333
<u>Sub-Saharan Africa</u>:				
Ivory Coast	99	0	99	198

TABLE XIX (Cont.)

Country	Missile Combatant Score	Diesel Submarine Score	Total (1976) Score	Future (1980) Score
Senegal	198	0	198	297
Somalia	599	0	599	599*
South Africa	0	634	634	2483+
<u>South Asia</u>:				
India	2001	1745	3746	4182+
Pakistan	0	486	486	486
<u>East and Southeast Asia</u>:				
Brunei	95	0	95	95
China (PRC)	36711	14002	50713	51829
Indonesia	2250	470	2720	2720
Korea (North)	4204	2542	6746	6746*
Korea (South)	420+	0	420+	630+
Malaysia	1209	0	1209	1955+
Singapore	1007	0	1007	1007
Taiwan	189	391	580	580+
Thailand	309	0	309	618
Vietnam	349	0	349	349

+ Additional units on order or in the current inventory. Lack of detailed information concerning numbers of units and/or performance characteristics precludes determining capability scores.

* Denotes nations which rely on the USSR and/or other Communist nations for naval weapons. Future unannounced deliveries by the USSR and/or other Communist suppliers are considered probable/possible.

TABLE XX

NATIONAL SEA DENIAL CAPABILITY SCORES

Scenario #2

Country	Missile Combatant Score	Diesel Submarine Score	Total (1976) Score	Future (1980) Score
Eastern Mediterranean:				
Greece	2105	1511	3616	4393
Turkey	272+	3297	3569+	4869+
Central and South America:				
Argentina	0	960	960	3109+
Brazil	0	1816	1816	2717
Chile	905	433	1338	1338
Columbia	0	428	428	428
Cuba	5025	0	5025	5025*
Ecuador	584	0	584	997
Peru	429	1394	1823	3093
Uruguay	0	0	0	411
Venezuela	768	556	1324	2790
North Africa and Middle East:				
Algeria	1524	0	1524	1524
Egypt	4274	2935	7209	7209
Iran	1903	0	1903	7575
Iraq	1942	0	1942	1942*
Israel	6228	294	6522	9669
Libya	343	190	533	7666
Morocco	185	0	185	1749
Saudi Arabia	0	0	0	0+
Syria	2572	0	2572	2572*
Tunisia	301	0	301	301
Sub-Saharan Africa:				
Ivory Coast	87	0	87	174

TABLE XX (Cont.)

Country	Missile Combatant Score	Diesel Submarine Score	Total (1976) Score	Future (1980) Score
Senegal	174	0	174	261
Scmalia	583	0	583	583*
South Africa	0	770	770	2914+
<u>South Asia</u>:				
India	1993	2111	4104	4632+
Pakistan	0	600	600	600
<u>East and Southeast Asia</u>:				
Brunei	95	0	95	95
China (PRC)	37409	16466	53875	55051
Indonesia	2205	543	2748	2748
Korea (North)	4235	3006	7241	7241*
Korea (South)	473+	0	473+	709+
Malaysia	1288	0	1288	2109+
Singapore	1165	0	1165	1165
Taiwan	212	459	671	671+
Thailand	351	0	351	702
Vietnam	349	0	349	349

+ Additicnal units on order or in the current inventory. Lack of detailed information concerning numbers of units and/or performance characteristics precludes determining capability scores.

* Denotes nations which rely on the USSR and/or other Communist nations for naval weapons. Future unannounced deliveries by the USSR and/or other Communist suppliers are considered probable/possible.

situation with respect to missile-carrying surface combatants and torpedo-firing diesel submarines. The third column gives aggregate capability scores. The fourth column displays the aggregate capability scores for each nation assuming the delivery of all systems currently contracted for and no retirement of existing systems. The tables have the advantages of being concise, easily interpreted and quickly updated as information concerning inventory changes becomes available. They present the decision maker with capability scores, rather than the relatively unsophisticated outputs of techniques displayed in Chapter III. They incorporate the capabilities which are inherent in the weapons platforms and take into account the ability of the recipient nation to effectively utilize the weapons. No other technique discovered to date has the ability to combine this number of complex factors into a sophisticated, yet easily understood, format. These advantages cannot be overstressed in an era of extreme demands on decision makers' time and the resultant reliance on meaningful research.

E. THE MIDDLE EAST CRISIS SCENARIO

What insights can be gained by application of the scores

to the 1980 crisis scenario postulated in Chapter I? MAUT focuses attention on a number of factors highlighted in that scenario. The implications which can be drawn will be demonstrated by taking each nation involved in that scenario in turn.

1. Kuwait: Kuwait has neither antiship missile combatants, nor diesel submarines. However, acquisition of antiship missile combatants is expected in the near future. Scores derived in this thesis suggest that Kuwait's best counter to the Iraqi naval build-up would be to purchase high capability ships such as the LA COMBATTANTE III PTFG with the EXOCET SSM to exploit the deficiencies of the OSA PTFGs in the Iraqi inventory (Table XVI) and to exploit the relatively low Iraqi personnel-related factors (Table XVIII) by developing or hiring a highly trained cadre of personnel.

2. Saudi Arabia: The judges considered the Saudis about equal to the Iraqis in the personnel-related areas (Table XVIII). Thus, relative capabilities become dependent on the numbers and military worth of the ships in each nation's inventory. The absence of information about the numbers and performance characteristics of the missile combatants to be provided as part of the Saudi Naval Expansion Program package

precludes further evaluation of the possible impact of the Saudi decision to support Kuwait in the hypothetical crisis situation.

3. Iraq: The platform capability scores in Table XV and XVI reveal that further Soviet deliveries of OSA PTFGs might be required in order for Iraq to retain a position of dominance over combined Kuwaiti and Saudi forces, especially if Kuwait were to acquire ships of the LA COMBATTANTE III PTFG caliber. The relatively poor score for the OSA PTFG in the war-at-sea situation, coupled with the unimpressive personnel-related score for Iraq, means that the Soviets would have to resupply Iraq with more than one OSA PTFG for each LA COMBATTANTE III PTFG introduced into the Kuwaiti inventory in order to maintain Iraqi superiority. An alternative would be to improve training and logistics support to raise Iraq's personnel-related score.

4. Iran: While Iraq and Iran are roughly equivalent in sea denial capabilities at the present time (Table XIX and XX), the Shah will clearly have the dominant navy in the Persian Gulf by 1980. This is a result of both the influx of significant numbers of very capable weapon platforms and the high personnel-related score assigned to Iran by the judges.

A force with these considerable capabilities operating in the confines of the Persian Gulf as described in the crisis scenario will be formidable.

5. Libya: Libyan sea denial capabilities are among the lowest in the Middle East at the present time. However, the influx of capable weapon platforms such as the PR-72 PTFG (Tables XV and XVI) will give President Qadhaafi one of the dominant Third World navies by 1980. If the rather dismal personnel-related score (Table XVIII) could be improved in the interim, Libyan capabilities could be expanded even further.

6. Egypt: It is realistic to assume that Egypt views the growing Libyan naval capabilities with concern. While Egypt is clearly dominant at present (Table XIX and XV), she may well be surpassed by Libya in the near future. The possibility that Egyptian units might have to be retired or scrapped for spare parts in the interim period further aggravates the Egyptian situation. The relatively high score for personnel-related factors indicates that an effort to improve Egyptian naval capabilities will have to concentrate on inventory augmentation with units comparable to the quality of the units being acquired by Libya. In short, by

1980 Egypt might be expected to call for outside support in the face of a Libyan blockade as was postulated in the hypothetical crisis scenario.

7. Israel: The overall capability scores show Israel to be roughly equivalent to Egypt as the dominant navy in the Eastern Mediterranean at present. This is clearly the case of meeting Egyptian quantity with Israeli quality as demonstrated by the scores. The orders which have been place for additional antiship missile and submarine platforms and the high quality personnel and support functions will improve Israel's relative position in the near future making her the single dominant naval force in the Eastern Mediterranean.

What of the concerns of the major naval powers over the threat of guerrilla-type attacks on Western shipping? The quantification of sea interdiction capabilities indicates that the concerns are legitimate and that the threat is growing. For example, in the foreseeable future the sea interdiction potential of nations cast in the scenario as being in opposition to the West will increase as follows (from Table XX):

1. Iran --- Up 400 percent over 1977 level.
2. Libya --- Up 1500 percent over 1977 level.

Other significant, if less spectacular, increases will occur at the same time in other, geographically dispersed parts of the Third World.

VII. CONCLUSIONS

This study has demonstrated a potential problem for Western nations who are dependent on sea lines of communication for supplies of vital resources. Third World navies are rapidly enlarging their sea interdiction capabilities and their capacity for limited-area sea denial. The increased capabilities are primarily embodied in large-scale acquisitions of antiship missile combatants and torpedo-firing diesel submarines. The magnitude of these acquisitions alone requires that the threat and the potential foreign policy implications which attend transfers of these systems be closely examined.

A survey of previous attempts to measure military capabilities reveals a need for improved analytic techniques. Arms transfer analysis in general requires meaningful inquiry into the military capabilities which are being transferred to Third World nations. Meaningful analysis is particularly important to evaluation of Third World naval capabilities because of the direct threat to Western interests which these

capabilities can pose. The immediacy of the threat has generated an urgent requirement for analytical techniques which can transcend inventory counting or dollar expenditure evaluations to analyze military capabilities.

Multi-Attribute Utility Theory as developed in the LeGrow thesis offers a technique for meaningful quantification of military capabilities. The theory behind the technique is sound. It produces ratio-level data which increases its usefulness and avoids the computational abuses which often accompany the use of interval-level data. The application of MAUT to the sea denial capabilities question resulted in three major findings.

1. MAUT is a workable technique. MAUT and the Constant Sum Method are both amenable to treatment in questionnaires. The required computations are easily explained and can be performed on a hand-held calculator. The two techniques operating in concert permit the incorporation of a wide range of expertise into the study. The results obtained are consistent with observed real-world phenomena.

2 MAUT is well suited to assessments of military capabilities. MAUT, augmented by the Constant Sum Method,

permits a comprehensive examination of the multi-faceted problem of quantifying military capabilities. It measures capabilities directly, rather than relying on surrogate measures such as weapon system cost. MAUT and the Constant Sum Method offer an optimal trade-off between realism and sophistication. They incorporate measurements of the important determinants of weapon system capabilities to present a realistic appraisal of military worth. In this regard they offer greater sophistication than current methods, but do not become encumbered in the complexities of computer programs and higher mathematics as do sophisticated combat models. Finally, the method has the flexibility required for imaginative application in the area of arms transfer analysis.

3. MAUT offers a meaningful policy-making tool. The technique described in this thesis can aid in bridging the chasm which often exists between the analyst immersed in the intricacies of a problem and the decision maker who remains a generalist. MAUT offers expert judgments presented in an easily understood format. The output is concise. Its flexibility permits tailoring the technique to answer the policy maker's specific questions. MAUT outputs can serve as excellent rules-of-thumb for a decision maker lacking the

requisite expertise to make direct evaluations of military capabilities.

A. SUBSTANTIVE ANALYSIS

The focus of this thesis has been on a thorough examination of the MAUT technique, rather than on substantive analysis. However, the presence of the real and growing potential threat from lesser developed nations' navies requires that major substantive findings be brought to the reader's attention.

1. Current analysis tends to understate the potential sea interdiction threat. Figures presented in Chapter II showed that Third World antiship missile combatant inventories will expand approximately 66 percent between 1977 and 1980. Inventories of diesel submarines will increase by approximately 33 percent over the same period. MAUT-derived scores taken from Table XIX and XX demonstrate that capabilities will increase in excess of 85 percent during that time period. Moreover, this dramatic increase is tremendously understated. It does not include Soviet-bloc transfers which might occur during the period. Non-Communist

transfers have been omitted where detailed information is lacking. But, more significantly, the 85 percent increase is based on present personnel-related factor scores. It is anticipated that additional training and operational experience obtained during the three-year period will add significantly to the 1980 capability scores.

2. <u>Concentrations of sea denial capabilities have occurred/are evolving in specific geographical regions</u>. Much of this concentration has taken place in areas which are particularly vital to Western interests. The Eastern Mediterranean is a case in point. In North Africa, the anticipated ten-fold increase in Moroccan capabilities and Libya's dramatic 1500 percent expansion may have profound implications for naval planners. Further, Libyan and Moroccan plans may spur increased acquisitions by neighboring Algeria, Tunisia and Egypt which will raise the concentration of naval capabilities in this area. Other areas of interest which evolve from MAUT analysis are South Africa, the Persian Gulf and the nations surrounding the Straits of Malacca. All have/will have dense concentrations of sea denial capabilities in restricted ocean areas.

3. <u>Transfers of technology greatly affect sea denial</u>

capabilities. The MAUT technique clearly demonstrates the significant impact which technology transfers have on sea denial potential. Transfers of ECM/DECM equipment, deliveries of sophisticated torpedoes and incorporation of antiship missile defenses can rapidly upgrade existing systems. Decisions to deliver follow-on missiles like the improved EXOCET could alter regional naval balances. The implications of technology transfers are dramatic because of the speed with which changes can occur. Lead time on delivery of new surface combatants and submarines could be five to seven years. Transfers of technology can occur within a matter of weeks or months.

4. Personnel and societal influences are often ignored. The judges rated personnel considerations approximately equal to weapon performance in determining the sea denial potential of lesser developed nations. Arms transfer analysis tends to overlook personnel and societal influences. In doing so it ignores extremely important factors.

MAUT analysis displayed two distinct groups of nations. The first grouping has largely realized its potential in personnel-related fields. This group is epitomized by Israel, South Africa and the PRC. These nations must

concentrate efforts to increase sea denial potential in the weapons acquisition/improvement areas. Each is currently pursuing this course of action.

The second group encompasses nations with potential which has not been realized because of low personnel-related scores. This group would be expected to attempt to increase sea denial potential by upgrading training, maintenance and logistics functions. The relative speed with which benefits can be realized, compared with the length of time required to acquire additional weapon systems, requires close examination of personnel-related factors.

B. SUGGESTIONS FOR FURTHER STUDY

Further study of Multi-Attribute Utility Theory is clearly warranted. Three areas of investigation are suggested.

1. Parallel research. Duplicate research in the area of sea denial capabilities is required to examine the reliability of the capability scores presented in this thesis. Sensitivity analysis should be accomplished to

determine whether the results were biased by the choice of experts or by the questionnaires utilized in the study.

2. <u>Expansion of MAUT</u>. MAUT should be expanded into additional areas of military capability analysis. Studies of other missions and scenarios are warranted. Investigation of additional missions and scenarios will further develop the mechanics of the technique.

3. <u>Utilize results for substantive analysis</u>. The study of sea denial capabilities suggests applications for MAUT in analysis of arms racing. Application of MAUT capability scores to simulations and projection techniques might be explored. Study of the interaction of geography and naval capabilities is is also required. For example, the PRC's tremendous naval capability score is significantly tempered by requirements placed on its navy by a long coastline and widely separated operating areas. A smaller concentration of sea denial capabilities in restricted waters such as the Straits of Malacca may prove to be far more significant.

Updated personnel-related factor scores, coupled with current platform capability scores for a wide variety of platforms and scenarios, would provide the basis for

responsive and meaningful research. MAUT has the ability to meet a decision maker's needs in quantifying military worth. The development of the necessary MAUT-derived scores and an in-depth exploration of potential applications of the technique remains to be accomplished.

LIST OF FOOTNOTES

[1]Third World inventories of antiship missile combatants and diesel submarines, plus anticipated deliveries are contained in Appendix A.

[2]Jane's Fighting Ships 1976-77, p. 125, Franklin Watts, Inc., 1976.

[3]D.M.S. Market Intelligence Report, Kuwait Summary p. 6, Defense Marketing Services, 1976.

[4]Ibid., Saudi Arabia Summary p. 13, states that the Saudi Naval Expansion Program (SNEP) undertaken by the U.S. will ultimately cost Saudi Arabia an estimated $1 Billion. The program includes at least 20 ships, some of which will be equipped with the HARPOON antiship missile system.

[5]Jane's 1976-77, op. cit., p.242.

[6]Sulzberger, C.L., "Arms Without the Man," N.Y. Times, v. CXXVI, p. 18, 8 January 1977.

[7]Jane's 1976-77, op. cit., p. 117.

[8]Statement of Admiral James L. Holloway III, USN, Chief of Naval Operations, concerning the FY 1977 Military Posture and the FY 1977 Budget of the United States Navy, p. 20, quoted in Eldridge, H.S. (CDR, USN), "Non-Superpower Sea Denial Capability: The Implications for Superpower Navies Engaged in Presence Operations," unpublished paper prepared for Conference on Implications of the Build-Up in Non-Industrial States, The Fletcher School of Law and Diplomacy, Tufts University, 6-8 May 1976, p. 76. (Not to be quoted or cited without permission.)

[9]Jane's 1976-77, op. cit., p. 91-92.

[10]Jane's 1976-77, op. cit., p. 92.

[11]Middendorf, J.W., II, "A 600 Ship Navy to Offset the Soviet Threat," Vital Speeches of the Day, v. 41, p. 706-708, 15 September 1975.

[12]Kemp, G., "The New Strategic Map: Geography, Arms Diffusion and the Southern Seas," p. 1-2, Unpublished paper prepared for Conference on Implications of the Military Build-Up in Non-Industrialized States, The Fletcher School of Law and Diplomacy, Tufts University, 6-8 May 1976. (Not to be quoted or cited without permission.)

[13]Abrahamsson, B.J. and Strechler, J.L., Strategic Aspects of Seaborne Oil, p. 38, Sage Publications, 1973.

[14]LaRocque, G. (RADM, USN ret.), "The Nth Country Submarine/ASW Problem," p. 234, 238. Tsipis, K., Cahn, A.H. and Feld, B.T. (Ed.), The Future of the Sea-Based Deterrent, The M.I.T. Press, 1973.

[15]Statistical Yearbook 1975, p. 191-192, United Nations Department of Economic and Social Affairs, 1976.

[16]Swinton, S.M., "Strait of Hormuz Is Gateway to 75 percent of Known Oil Reserves," (Associated Press), Monterey Peninsula Herald, v. LXXXVII, p. 18, 21 December 1976.

[17]Ibid., p. 18.

[18]Zumwalt, E.R., Jr. (ADM, USN ret.), On Watch, p. 452-453, Quadrangle, 1976.

[19]Transfers of sea denial capabilities to countries variously described as "underdeveloped", "lesser developed" or "Third World" are addressed. The list of underdeveloped countries with significant naval capabilities contained in SIPRI Yearbook 1975 formed the basis for inclusion in this thesis. Additional nations accepted as "lesser developed" (Brunei, Senegal, Somalia) were added. Three "developed" nations (Greece, South Africa, Turkey) were included because of their reliance on foreign sources for naval weapons.

[20]Jane's 1976-77, op. cit., p. 117.

[21]Jane's 1976-77, op. cit., p. 117.

[22]Stockholm International Peace Research Institute, World Armaments and Disarmament: SIPRI Yearbook 1975, p. 279-280, The M.I.T. Press, 1975.

[23]Kaul, R. (LCDR, Indian Navy ret.), "The Indo-Pakistani War and the Changing Balance of Power in the Indian Ocean," U.S. Naval Institute Proceedings, v. 99, p. 172-195, May 1973.

[24]Shlomo, E. (RADM, Israeli Navy ret.), "Israeli SAAR FPBs Pass Combat Test in Yom Kippur War," U.S. Naval Institute Proceedings, v. 100, p. 115-118, September 1974.

[25]Jane's Fighting Ships 1976-77 published reports that India has ordered an unknown number of NANUCHKA PGGs from the Soviet Union. These units normally carry the SS-N-9 antiship missile. Whether this modern Soviet missile will be exported remains to be seen.

[26]A number of reports of HARPOON sales have been noted. They include a report in Jane's Fighting Ships 1976-77 that Iran has ordered 222 HARPOON antiship missiles.

[27]A detailed breakdown of missile combatant deliveries and deletions by country is contained in Appendix A.

[28]The Soviet WHISKEY SS is based on World War II German design. The BALAO SSs which have been exported were constructed in the 1944-45 period. A number of this class have already been retired by Third World recipients. (See Appendix A.)

[29]The West German TYPE 209 SS, which is currently being produced is an example of the level of sophistication available to Third World recipients.

[30]The TYPE 209, for example, is capable of 22 knots dived and carries the wire-guided SST-4 active/passive sonar homing torpedo. (See Jane's 1976-77.)

[31]Stockholm International Peace Research Institute, Arms Trade Registers: The Arms Trade with the Third World, p. 20, The M.I.T. Press, 1975.

[32]Jane's 1976-77, op. cit., p. 301.

[33]Jane's 1976-77, op. cit., p. 452.

[34]Jane's 1976-77, op. cit., p. 439.

[35]SIPRI Yearbook 1975, op. cit., p. 241.

[36]SIPRI Register, op. cit., p. 95-96. SIPRI Yearbook

1975, op. cit., p. 239. Jane's 1976-77, op. cit., p. 398.

[37]Argentina intends to mount EXOCETs on five FLETCHER DDs and on two SUMNER DDs and will purchase six TYPE 21 DDGSs from Britain. Brazil will place missiles on two of six Vosper MK-10 DDGSs ordered from Britain. India has mounted the SS-N-2 system on one WHITBY DD and reportedly has ordered a number of NANUCHKA PGGs from the USSR (See Appendix A.)

[38]D.M.S. Market Intelligence Report, op. cit., Iran Summary p. 6.

[39]D.M.S. Market Intelligence Report, op. cit., Iran Summary p. 25.

[40]D.M.S. Market Intelligence Report, op. cit., Saudi Arabia Summary p. 13.

[41]General Dynamics-Pamona Division, The World's Missile Systems, General Dynamics, February 1975 cites the following missile costs: EXOCET--$200,000, OTOMAT--$280,000, GABRIEL--$85-$95,000, SEAKILLER I--$60,000, PENGUIN--$7,000.

[42]Ocean Science News, v. 18, p. 4, 6 February 1976.

[43]Stockholm International Peace Research Institute, Oil and Security, p. 49, Humanities Press, 1974.

[44]Ibid., p. 132-139.

[45]Cunha, G.D.M., Jr., and Kline, R.D., A Methodological Approach to Ocean Politics, Masters Thesis, Naval Postgraduate School, March 1973.

[46]See Gurr, T.R., Politimetrics: An Introduction to Quantitative Macropolitics, p. 5-9, Prentice-Hall, 1972.

[47]LeGrow, A.W., Measuring Aircraft Capability for Military and Political Analysis, p. 29, Masters Thesis, Naval Postgraduate School, March 1976.

[48]International Institute for Strategic Studies, The Military Balance 1974-1975, Preface, International Institute for Strategic Studies, 1974.

[49]L.A. Times, p. 2, 3 September 1976.

[50]Ibid. p. 2.

[51]"A particular measurement procedure or indicator is reliable to the extent that it yields results that are consistent in successive measurements of the same case, and comparable among cases." Gurr, op. cit., p. 49.

[52]"A measure or indicator is valid if it is an adequate measure of what it is supposed to represent." Gurr, op. cit., p. 43.

[53]Eldridge, op. cit., p. 45.

[54]Ibid., p. 45.

[55]Jane's Weapons Systems 1977, p. 57-59, Franklin Watts, 1976.

[56]SIPRI Yearbook 1975,, op. cit., p. 255.

[57]LeGrow, A.W., Measuring Aircraft Capability for Military and Political Analysis, Masters Thesis, Naval Postgraduate School, March 1976.

[58]Rattinger, H., "From War to War to War: Arms Races in

the Middle East," *International Studies Quarterly*, v. 20, p. 501-532, December 1976.

[59]*Ibid*., p. 503.

[60]Mihalka, M., "The Measurement and Modeling of Arms Accumulation: The Middle East as a Case Study," M.I.T. Center for International Studies publication C/175-8, 1975.

[61]Rattinger, *op. cit*., p. 512.

[62]Rattinger, *op. cit*., p. 512.

[63]Ordinal-level measurement is characterized by ordering or ranking instances on a continuum. See Stevens, S.S., *Handbook of Experimental Psychology*, p. 26, Whiley, 1951.

[64]Interval-level measurement is characterized by an arbitrary origin or base and an arbitrary unit which is constant over the scale. *Ibid*., p. 27.

[65]Ratio-level measurement is characterized by a fixed or natural origin and an arbitrary unit which is constant over the scale. See Stevens, *op. cit*., p. 28-29.

[66]C.A.C.I., *Final Technical Report-Developmental Methodologies for Medium- to Long-Range Estimates: User's Manual for Soviet Force Effectiveness Model*, p. 1, C.A.C.I., Inc., September 1976.

[67]*Ibid*., p. 8.

[68]Bode, J.R., *Indices of Effectiveness in General Purpose Force Analysis*, Braddock, Dunn and McDonald, Inc., October 1974.

[69]*Ibid*., p. 1.

[70]*Ibid*., p. 1.

[71]*Ibid*., p. 2.

[72]*Ibid*., p. 2.

[73]*Ibid*., p. 1.

[74]Neu, C.R., *Attacking Hardened Air Bases (AHAB): A Decision Analysis Aid for the Tactical Commander*, RAND, August 1974.

[75]Barclay, S. and Peterson, C.R., *Multi-Attribute Utility Models for Negotiations*, Decisions and Designs, Inc., March 1976.

[76]LeGrow, *op. cit*., p. 121.

[77]The two assumptions necessary for ratio-level measurement are: (1) that the zero point demanded of the judge and defined as the threshold value at which the attribute ceases to be useful to the specified mission is an absolute zero point and can be considered a "natural" origin; and (2) that the judge is capable of making reasonably precise judgments of the value of an attribute. See LeGrow, *op. cit*., p. 128.

[78]Edwards, W., Guttentag, M. and Snapper, K., "A Decision-Theoretic Approach to Evaluation Research," p. 139-181. Struening, E.L. and Guttentag, M. (Ed.), *Handbook of Evaluation Research*, v. I, Sage Publications, 1975.

[79]*Ibid*., p. 152-153.

[80]LeGrow, *op. cit.*, p. 128.

[81]LeGrow, *op. cit.*, p. 128.

[82]LeGrow, *op. cit.*, p. 124.

[83]*Jane's 1976-77*, *op. cit.*, p. 243.

[84]An extensive survey of the literature is contained in Kirkwood, C.W., *Decision Analysis Incorporating Preferences of Groups*, Technical Report No. 74, Operations Research Center, M.I.T., June 1972. See Giauque, W.C., *A Multi-Attribute Approach to Measure Quality of Health Care*, Naval Postgraduate School, March 1976, for a complete bibliography.

[85]Kirkwood, *op. cit.*, p. 10 and Chapter 3.

[86]Edwards, Guttentag and Snapper, *op. cit.*, p. 159.

[87]Kirkwood, *op. cit.*, p. 13.

[88]Edwards, Guttentag and Snapper, *op. cit.*, p. 155.

[89]LeGrow, *op. cit.*, p. 125.

[90]LeGrow, *op. cit.*, Appendix IV.

[91]LeGrow, *op. cit.*, p. 125, 126.

[92]LeGrow, *op. cit.*, p. 127.

[93]*Jane's Weapons Systems 1977*, *op. cit.*, p. 60.

[94]*Jane's Weapons Systems 1977*, *op. cit.*, p. 68.

[95]*Jane's Weapons Systems 1977*, *op. cit.*, p. 61.

[96]*Jane's Weapons Systems 1977*, *op. cit.*, p. 61.

[97]*Jane's Weapons Systems 1977*, p. 59-62 reports that two new versions of the EXOCET (MM-39 and MM-40) and improvements to the SEAKILLER SSM are also currently under development.

[98]The Soviet reluctance to export recently developed naval missiles raises questions as to whether NANUCHKAs transferred to India would mount the SS-N-9 and SA-N-4 systems. Too much conjecture would be required to develop utility scores for this class given present uncertainties.

[99]*Jane's 1976-77*, *op. cit.*, p. 103.

[100]*Jane's 1976-77*, *op. cit.*, p. 103.

[101]*Jane's 1976-77*, *op. cit.*, p. 700.

[102]*Jane's 1976-77*, *op. cit.*, p. 700.

[103]*Jane's 1976-77*, *op. cit.*, p. 698.

[104]Rattinger, *op. cit.*, p. 503

[105]LeGrow, *op. cit.*, p. 134-136.

[106]Torgerson, W.S., *Theory and Methods of Scaling*, p. 104-106, Wiley, 1958.

[107]*Ibid.*, p. 105.

[108]Torgerson, *op. cit.*, p. 108-112.

[109]Presented by Dr. C.F. Lindsay in his course "Finite

Scaling Techniques" at the Naval Postgraduate School, July 1976.

[110]Stevens, op. cit., p. 28.

[111]LeGrcw, op. cit., p. 125-127. Giauque, W.C., Prevention and Treatment of Streptococcal Sore Throat and Rheumatic Fever--A Decision Theoretic Approach, Ch. 4, Ph. D. Thesis, Harvard University, 1972.

[112]Eldridge, op. cit., p. 59.

APPENDIX A

THIRD WORLD INVENTORIES

AREA/RECIPIENT	DELIVERIES	DELETIONS	REMARKS/SOURCES
Mediterranean Area			
Greece			
GATO SS	1-1957		Jane's 1968-69; SIPRI Register.
	1-1958		Jane's 1969-70; SIPRI Register.
		1-1967	Jane's 1969-70.
		1-1972	Jane's 1974-75.
BALAO SS	2-1965		Jane's 1976-77; SIPRI Register.
		1-1975	Jane's 1976-77.
		1-1976	Jane's 1976-77.
GUPPY IIA SS	1-1972		Jane's 1976-77; SIPRI Register.
GUPPY III SS	1-1973		Jane's 1976-77.
TYPE 209 SS	1-1971		Jane's 1976-77.
	2-1972		Jane's 1976-77.

AREA/RECIPIENT	DELIVERIES	DELETIONS	REMARKS/SOURCES
TYPE 209 SS (Cont.)	1-1973		*Jane's* *1976-77*.
	3 Ordered		*Jane's* *1976-77* - Order placed in 1975; Option on fourth unit.
LA COMBATTANTE II PTFG	1-1971		*Jane's* *1976-77*.
	3-1972		*Jane's* *1976-77*.
LA COMBATTANTE III PTFG	4-1976		*Jane's* *1976-77*.
Turkey			
BURAH SS	3-1945		*Jane's* *1947-48*.
		3-1957	*Jane's* *1967-68*.
SALDIRAZ SS	2-1945		*Jane's* *1947-48*.
		2-1957	*Jane's* *1967-68*.
BALAC SS	2-1948		*Jane's* *1950-51*.
	2-1950		*Jane's* *1969-70*; *SIPRI* *Register*.
	2-1954		*Jane's* *1969-70*; *SIPRI* *Register*.
	1-1957		*Jane's* *1969-70*.
	1-1958		*Jane's* *1969-70*; *SIPRI* *Register*.
	2-1960		*Jane's* *1969-70*; *SIPRI* *Register*.

AREA/RECIPIENT	DELIVERIES	DELETIONS	REMARKS/SOURCES
BALAC SS (Cont.)		1-1953	*Jane's 1969-70*.
		5-1973	*Jane's 1976-77*.
		2-1974	*Jane's 1976-77*.
GUPPY IA SS	1-1972		*Jane's 1976-77*; *SIPRI Register*.
GUPPY IIA SS	2-1971		*Jane's 1976-77*.
	4-1972		*Jane's 1976-77*.
	1-1973		*Jane's 1976-77*.
GUPPY III SS	2-1973		*Jane's 1976-77*.
	2 Ordered		*Jane's 1976-77*; (Transfer delayed by U.S. arms embargo).
TYPE 209 SS	2-1975		*Jane's 1976-77*.
	3 Ordered		*Jane's 1976-77*.
LA COMBATTANTE III PTFG	1-1976		*Jane's 1976-77*.
	3 Ordered		*Jane's 1976-77*.
JAGUAR PTG	4-1975		*Jane's 1976-77* (Unknown type of SSMs placed on 4 of 9 units inventory in 1975); *SIPRI Register* (EXOCET sale to arm patrol boats).

AREA/RECIPIENT	DELIVERIES	DELETIONS	REMARKS/SOURCES
Central and South America Area			
Argentina			
BALAO SS	2-1960		Jane's 1970-71; SIPRI Register.
		2-1972	Jane's 1974-75.
GUPPY IA SS	1-1971		Jane's 1976-77; SIPRI Register.
GUPPY II SS	1-1971		Jane's 1976-77; SIPRI Register.
TYPE 209 SS	2-1974		Jane's 1976-77; SIPRI Yearbook 1975.
LURSEN 45-METER PTFG	2 Ordered		Jane's 1976-77; SIPRI Yearbook 1975.
FLETCHER DDGS	5 Ordered		Jane's 1976-77; (To be fitted with unknown number of EXOCET).
ALLEN SUMNER DDGS	2 Ordered		Jane's 1976-77; (To be fitted with unknown number of EXOCET).
TYPE 21 DDGS	6 Ordered		Jane's 1976-77; SIPRI Yearbook 1975.

AREA/RECIPIENT	DELIVERIES	DELETIONS	REMARKS/SOURCES
Brazil			
GATO SS	2-1957		Jane's 1967-68; SIPRI Register.
		1-1967	Jane's 1970-71.
		1-1968	Jane's 1970-71.
BALAO SS	2-1963		Jane's 1970-71; SIPRI Register.
		2-1972	Jane's 1974-75.
GUPPY II SS	3-1972		Jane's 1976-77; SIPRI Register.
	2-1973		Jane's 1976-77.
GUPPY III SS	2-1973		Jane's 1976-77.
OBERON SS	1-1973		Jane's 1976-77; SIPRI Register.
	2 Ordered		Jane's 1976-77.
VOSPER MK-10 DDGSP	2 Ordered		Jane's 1976-77; SIPRI Register.
Chile			
BALAO SS	2-1961		Jane's 1970-71; SIPRI Register.
		1-1972	Jane's 1976-77.
		1-1975	Jane's 1976-77.
OBERON SS	2-1976		Jane's 1976-77.

AREA/RECIPIENT	DELIVERIES	DELETIONS	REMARKS/SOURCES
ALMIRANTE WILLIAMS DDGS	1-1974		*Jane's 1976-77* (Conversion completed 1974).
	1-1975		*Jane's 1976-77* (Conversion completed 1975).
LEANDER DDGS	2-1975		*Jane's 1976-77*.
Columbia			
TYPE 209 SS	2-1975		*Jane's 1976-77*.
Cuba			
KOMAR PTG	12-1962		*Jane's 1976-77*; *SIPRI Register*.
	6-1966		*Jane's 1976-77*.
OSA PTFG	2-1972		*Jane's 1976-77*; *SIPRI Register*.
	3-1973		*Jane's 1976-77*.
Ecuador			
TYPE 209 SS	2 Ordered		*Jane's 1976-77*.
LURSEN 45-METER PTFG	3-1976		*Jane's 1976-77*.

AREA/RECIPIENT	DELIVERIES	DELETIONS	REMARKS/SOURCES
Peru			
'R-Class' SS	2-1926		Jane's 1958-59.
	2-1928		Jane's 1958-59.
		4-1960	Jane's 1970-71.
TIBURON SS	2-1954		Jane's 1967-68; SIPRI Register.
	2-1957		Jane's 1967-68; SIPRI Register.
GUPPY IA SS	2-1975		Jane's 1976-77.
TYPE 209 SS	1-1974		Jane's 1976-77.
	1-1975		Jane's 1976-77.
	2 Ordered		Jane's 1976-77.
DARING DDGS	2-1973		Jane's 1976-77.
MOD-LUPO DDGS	4 Ordered		Jane's 1976-77; SIPRI Yearbook 1975.

AREA/RECIPIENT	DELIVERIES	DELETIONS	REMARKS/SOURCES
Uruguay			
TYPE 209 SS	2 Ordered		Jane's 1976-77.
Venezuela			
BALAO SS	1-1960		Jane's 1976-77; SIPRI Register.
GUPPY II SS	1-1972		Jane's 1976-77; SIPRI Register.
	1-1973		Jane's 1976-77; SIPRI Register.
TYPE 209 SS	1-1976		Jane's 1976-77.
	1 Ordered		Jane's 1976-77; SIPRI Register.
VOSPER 37-METER PTFG	3-1975		Jane's 1976-77.
LUPO DDGS	6 Ordered		Jane's 1976-77; SIPRI Register.
Middle East and North Africa			
Algeria			
KOMAR PTG	6-1967		Jane's 1976-77.
OSA PTFG	3-1967		Jane's 1976-77.

AREA/RECIPIENT	DELIVERIES	DELETIONS	REMARKS/SOURCES
Egypt[1]			
WHISKEY SS	4-1957		*Jane's 1976-77*; *SIPRI Register*.
	3-1958		*Jane's 1976-77*; *SIPRI Register*.
	1-1962		*Jane's 1976-77*; *SIPRI Register*.
	2-1971		*Jane's 1976-77*.
		2-1966	*Jane's 1976-77*.
		2-1971	*Jane's 1976-77*.
ROMEO SS	5-1966		*Jane's 1976-77*; *SIPRI Register*.
	(1)-1969		*Jane's 1976-77*; *SIPRI Register*.
KOMAR PTG	(2)-1963		*Jane's 1974-75* (Deliveries 1962-67).
	(2)-1964		*Jane's 1974-75* (Deliveries 1962-67).
	(1)-1965		*Jane's 1974-75* (Deliveries 1962-67).
	(1)-1966		*Jane's 1974-75* (Deliveries 1962-67).
	(1)-1967		*Jane's 1974-75* (Deliveries 1962-67).

AREA/RECIPIENT	DELIVERIES	DELETIONS	REMARKS/SOURCES
KOMAR PTG (Cont.)	(3)-1975		*Jane's 1976-77* (Six built in Egypt 1975-76).
	(3)-1976		*Jane's 1976-77* (Six built in Egypt 1975-76).
		1-1970	*Jane's 1974-75* (Sunk by Israeli aircraft).
		2-1973	*Jane's 1974-75* (Sunk during October 1973 war).
OSA PTFG	10-1966		*Jane's 1976-77*.
		4-1973	*Jane's 1976-77* (Sunk during October 1973 war).
Iran			
TANG SS[2]	3 Ordered		*Jane's 1976-77*.
BATTLE DDGS	1-1975		*Jane's 1976-77* (Conversion completed in 1975).
ALLEN SUMNER DDGS	2-1972		*Jane's 1976-77*.

AREA/RECIPIENT	DELIVERIES	DELETIONS	REMARKS/SOURCES
VOSPER MK-5 DDGS	2-1971		*Jane's 1976-77*; *SIPRI Register*.
	2-1972		*Jane's 1976-77*; *SIPRI Register*.
SPRUANCE DDGSP	4 Ordered		*Jane's 1976-77*; *DMS Market Intelligence Reports*.
LA COMBATTANTE II PTFG	12 Ordered		*Jane's 1976-77*.
Iraq			
OSA PTFG	(3)-1973		*Jane's 1974-75*.
	(2)-1974		*Jane's 1975-76*; *SIPRI Yearbook 1975*.
	(1)-1975		*Jane's 1976-77*.
OSA II PTFG	(2)-1975		*Jane's 1975-76*.
	(2)-1976		*Jane's 1976-77*.
Israel			
T-CONVERSION SS	1-1967		*Jane's 1976-77*.
	1-1968		*Jane's 1976-77*.
		1-1967	*Jane's 1976-77* (Unit sank).

AREA/RECIPIENT	DELIVERIES	DELETIONS	REMARKS/SOURCES
TYPE 206 SS	3 Ordered		Jane's 1976-77; SIPRI Yearbook 1975.
RESHEF/SAAR II/III PTG	7-1969		Jane's 1976-77.
	5-1970		Jane's 1976-77.
RESHEF/SAAR IV PTFG	2-1973		Jane's 1976-77.
	2-1974		Jane's 1976-77.
	2-1975		Jane's 1976-77.
	6 Ordered		Jane's 1976-77.
Libya			
FOXTROT SS	1-1977		N.Y. Times, 8 January 1977.
	5 Ordered		Washington Post, 20 July 1975.
BRAVE PTGL	3-1969		Jane's 1976-77; SIPRI Register.
PR-72 PTFG	10 Ordered		Jane's 1976-77.
CSA PTFG	24 Ordered		Jane's 1976-77.

AREA/RECIPIENT	DELIVERIES	DELETIONS	REMARKS/SOURCES
Morocco			
PR-72 PTFG[3]	1-1976		Jane's 1976-77.
	3 Ordered		Jane's 1976-77; DMS Market Intelligence Report; SIPRI Yearbook 1975 (To carry EXOCET).
OSA II PTFG	6 Ordered		DMS Market Intelligence Reports.
Saudi Arabia			
U.S.-Built PGG	Unknown		DMS Market Intelligence Reports (Part of SNEP program); SIPRI Yearbook 1975.
Syria			
KOMAR PTG	(2)-1963		Jane's 1970-71; SIPRI Register.
	(2)-1964		Jane's 1970-71; SIPRI Register.

AREA/RECIPIENT	DELIVERIES	DELETIONS	REMARKS/SOURCES
KOMAR PTG (Cont.)	(2)-1965		*Jane's 1970-71*; *SIPRI Register*.
	3-1976		*Jane's 1976-77*.
		3-1973	*Jane's 1974-75* (Sunk during October 1973 war).
OSA PTFG	(2)-1972		*SIPRI Register*.
	(2)-1973		*SIPRI Register*.
	3-1974		*Jane's 1974-75*; *SIPRI Yearbook 1975*.
	(1)-1975		*Jane's 1976-77*.
		2-1973	*Jane's 1974-75* (Sunk during October 1973 war).
Tunisia			
P-48 PGMGL	2-1970		*Jane's 1976-77*.
	1-1975		*Jane's 1976-77*.
Sub-Sahara Africa			
Ivory Coast			
P-48 PGMGL	1-1968		*Jane's 1976-77*; *SIPRI Register*.
	1 Ordered		*Jane's 1976-77*; *SIPRI Yearbook 1975*.

AREA/RECIPIENT	DELIVERIES	DELETIONS	REMARKS/SOURCES
Senegal			
P-48 PGMGL	1-1971		Jane's 1976-77; SIPRI Register.
	1-1974		Jane's 1976-77.
	1 Ordered		Jane's 1976-77.
Somalia			
OSA II PTFG	3-1975		Jane's 1976-77.
South Africa			
DAPHNE SS	1-1970		Jane's 1976-77; SIPRI Register.
	2-1971		Jane's 1976-77; SIPRI Register.
AGOSTA SS	2 Ordered		Jane's 1976-77.
RESHEF/SAAR PTFG	6 Ordered		Jane's 1976-77.
Frigate*	6 Ordered		Jane's 1976-77.

AREA/RECIPIENT	DELIVERIES	DELETIONS	REMARKS/SOURCES
South Asia			
India			
FOXTROT SS	1-1968		Jane's 1976-77; SIPRI Register.
	1-1969		Jane's 1976-77; SIPRI Register.
	2-1970		Jane's 1976-77; SIPRI Register.
	2-1973		Jane's 1976-77.
	2-1975		Jane's 1976-77.
	2 Ordered		Jane's 1976-77.
OSA PTFG	8-1971		Jane's 1976-77.
		1-1975	Jane's 1976-77 (Stripped to equip WHITBY DDGS).
WHITBY DDGS	1-1975		Jane's 1976-77.
NANUCHKA PGG[5]	Unknown		Jane's 1976-77.
Pakistan			
DAPHNE SS	3-1970		Jane's 1976-77; SIPRI Register.

AREA/RECIPIENT	DELIVERIES	DELETIONS	REMARKS/SOURCES
Far East			
Brunei			
BRAVE PTGL	1-1972		*Jane's 1976-77*; *SIPRI Register*.
China (PRC)			
SHSHUKA SS	(2)-1954		*Jane's 1970-71*.
	(2)-1955		*Jane's 1970-71*.
		4-1963	*Jane's 1970-71*.
"S-1 CLASS" SS	(2)-1954		*Jane's 1970-71*.
	(2)-1955		*Jane's 1970-71*.
		1-1972	*Jane's 1972-73*.
		1-1974	*Jane's 1975-76* (Remaining units capable of training functions only).
"M-V CLASS" SS	(2)-1954		*Jane's 1970-71*.
	(2)-1955		*Jane's 1970-71*.
		2-1973	*Jane's 1974-75*.
		1-1975	*Jane's 1976-77* (Remaining unit nearing end of service life).

AREA/RECIPIENT	DELIVERIES	DELETIONS	REMARKS/SOURCES
WHISKEY SS	(2)-1956		Jane's 1976-77.
	(2)-1957		Jane's 1976-77.
	(2)-1958		Jane's 1976-77.
	(3)-1959		Jane's 1976-77.
	(3)-1960		Jane's 1976-77.
	(3)-1961		Jane's 1976-77.
	(3)-1962		Jane's 1976-77.
	(3)-1963		Jane's 1976-77.
GOLF SSB	1-1964		Jane's 1976-77.
ROMEO SS	4-1967		Jane's 1976-77.
	2-1971		Jane's 1976-77.
	(6)-1972		Jane's 1976-77.
	(6)-1973		Jane's 1976-77.
	(6)-1974		Jane's 1976-77.
	(6)-1975		Jane's 1976-77.
	(6)-1976		Jane's 1976-77.

AREA/RECIPIENT	DELIVERIES	DELETIONS	REMARKS/SOURCES
HAN SS(N)	1-1974		*Jane's 1976-77.*
MING SS	1-1974		*Jane's 1976-77.*
	1 Ordered		*Jane's 1976-77.*
KOMAR/HOKU PTG	1-1965		*Jane's 1971-72.*
	2-1967		*Jane's 1971-72.*
	(2)-1968		*Jane's 1972-73.*
	(2)-1969		*Jane's 1972-73.*
	(2)-1970		*Jane's 1972-73.*
	(1)-1971		*Jane's 1972-73.*
	(10)-1972		*Jane's 1976-77.*
	(10)-1973		*Jane's 1974-75.*
	(10)-1974		*Jane's 1976-77.*
	(10)-1975		*Jane's 1976-77.*
	(10)-1976		*Jane's 1976-77.*
OSA/HOLA PTFG	1-1965		*Jane's 1971-72.*
	(2)-1966		*Jane's 1971-72.*
	(2)-1967		*Jane's 1971-72.*
	(2)-1968		*Jane's 1971-72.*
	(3)-1971		*Jane's 1971-72.*
	(10)-1972		*Jane's 1974-75.*

AREA/RECIPIENT	DELIVERIES	DELETIONS	REMARKS/SOURCES
OSA/HCLA PTFG (Cont.)	(10)-1973		Jane's 1976-77.
	(10)-1974		Jane's 1974-75.
	(10)-1975		Jane's 1975-76.
	(10)-1976		Jane's 1976-77.
LUTA DDGS	1-1971		Jane's 1976-77.
	2-1972		Jane's 1976-77.
	1-1973		Jane's 1976-77.
	3 Ordered		Jane's 1976-77.
GORDYY DDGS	1-1972		Jane's 1976-77.
	2-1973		Jane's 1976-77.
	1-1974		Jane's 1976-77.
RIGA DEGS	2-1973		Jane's 1976-77.
	2-1974		Jane's 1976-77.

AREA/RECIPIENT	DELIVERIES	DELETIONS	REMARKS/SOURCES
Indonesia			
WHISKEY SS	2-1959		Jane's 1970-71; SIPRI Register.
	(4)-1960		SIPRI Register.
	(4)-1961		SIPRI Register.
	4-1962		Jane's 1970-71; SIPRI Register.
		2-1970	Jane's 1970-71 (Two units used as source for spare parts).
		2-1972	Jane's 1972-73.
		7-1974	Jane's 1975-76.
KOMAR PTG	(2)-1961		Jane's 1976-77; SIPRI Register.
	(2)-1962		Jane's 1976-77; SIPRI Register.
	(2)-1963		Jane's 1976-77; SIPRI Register.
	4-1964		Jane's 1976-77; SIPRI Register.
	2-1965		Jane's 1976-77; SIPRI Register.
Korea (North)			
WHISKEY SS	2-1967		SIPRI Register.
	2-1971		SIPRI Register.

AREA/RECIPIENT	DELIVERIES	DELETIONS	REMARKS/SOURCES
ROMEO SS	2-1973		*Jane's 1976-77*.
	2-1974		*Jane's 1976-77*.
	3-1975		*Jane's 1976-77*.
	2-1976		*Jane's 1976-77*.
KOMAR PTG	4-1968		*SIPRI Register*.
	(2)-1969		*SIPRI Register*.
	(2)-1970		*SIPRI Register*.
	(2)-1971		*SIPRI Register*.
OSA PTFG	4-1968		*Jane's 1976-77*.
	2-1969		*Jane's 1976-77*.
	2-1972		*Jane's 1976-77*.
Korea (South)			
Large Surface Ships[6]	Unknown		*Jane's 1976-77*.
ASHVILLE PGG	2-1975		*Jane's 1976-77*.
	1-1976		*Jane's 1976-77*.
	1 Ordered		*Jane's 1976-77*.
U.S. CPIC Design	1-1975		*Jane's 1976-77* (Possible STANDARD or GABRIEL SSM platform).
	4 Ordered		*Jane's 1976-77*.

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QUANTITATIVE ASSESSMENT OF THIRD WORLD SEA DENIAL CAPABILITIES.(U)
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AREA/RECIPIENT	DELIVERIES	DELETIONS	REMARKS/SOURCES
1600-Ton Frigate	4 Ordered		Jane's 1976-77 (To carry SSMs).
Malaysia			
BRAVE PTGL	4-1971		Jane's 1976-77; SIPRI Register.
LA COMBATTANTE II PTFG	4-1973		Jane's 1976-77; SIPRI Register.
	4 Ordered		Jane's 1976-77.
150-Foot Missile Boats	6 Ordered		Jane's 1976-77 (Malaysian equivalent of RESHEF/SAAR).
SINGAPORE			
LA COMBATTANTE II PTFG	2-1972		Jane's 1976-77; SIPRI Register.
	2-1974		Jane's 1976-77.
	2-1975		Jane's 1976-77.

AREA/RECIPIENT	DELIVERIES	DELETIONS	REMARKS/SOURCES
Taiwan			
GUPPY II SS	2-1973		*Jane's 1976-77*; *SIPRI Register*.
ALLEN SUMNER DDGS	1-1976		*Jane's 1976-77* (Converted to carry SSMs).
	Unknown		*Jane's 1976-77* (Additional conversions possible from seven remaining SUMNER DDs).
Thailand			
LURSEN 45-Meter PTFG	2-1976		*Jane's 1976-77*.
	2 Ordered		*Jane's 1976-77*.
Vietnam			
KOMAR PTG	4-1972		*Jane's 1976-77*; *SIPRI Register*.
		2-1972	*Jane's 1976-77* (Sunk by U.S. aircraft).

*Numbers enclosed in parentheses represent approximations derived by apportioning total units delivered over a period of years to specific years within the time span.

Footnotes

1 *Jane's 1976-77* page 808: "Contract negotiations reported in July 1976 with Vosper-Thornycroft for refits of Soviet-built fast attack craft. Interest in construction of ten new craft also reported with possibility of British construction of submarines and frigates."

2 *Jane's 1976-77* page 325: "Designed to provide training for the establishment of a larger submarine force."

3 *Jane's 1976-77* page 325: "This type can be fitted with EXOCET...as the Vega control system will be installed this would be a simple operation."

4 *Jane's 1976-77* page 398: "In February 1975 it was announced that six frigates, to be armed with GABRIEL missiles, were to be built in Durban."

5 *Jane's 1976-77* page 230: "Reliably reported that a number of 'NANUCHKA' class missile corvettes are to be transferred from USSR. This would present problems over the release of a new type of missile but, if confirmed would give the Indians a notable increase in aggressive capability."

6 *Jane's 1976-77* page 301: "Several large ships of the Korean Navy have been armed with U.S. STANDARD surface-to-surface missiles." (Possible platforms include two GEARING DDs transferred in 1972, two GEARING DDs scheduled for 1976-77 transfer, two SUMNER DDs transferred in 1973 and three FLETCHER DDs transferred in 1963 and 1968).

APPENDIX B

ANTISHIP MISSILE COMBATANT QUESTIONNAIRE

NAVAL POSTGRADUATE SCHOOL
Monterey, California

From: Curricular Officer, Naval Intelligence Curriculum (Code-38)
To:

Subj: Student Questionnaire; distribution of

Encl: (1) Sea Denial Capabilities Questionnaire

1. Enclosure 1 represents one part of a student research project currently underway at the Naval Postgraduate School which is designed to measure the military worth of small, missile-equipped surface combatants. Results of this questionnaire will be incorporated into a thesis being prepared by LT Lowell E. Jacoby as a degree requirement in the Naval Intelligence Curriculum.

2. Distribution of this questionnaire has been greatly constrained by the lack of personnel within the U.S. Navy structure with expertise in the area of anti-ship missile capabilities and/or experience with small combatants of the type being employed by lesser developed nations as anti-ship missile platforms. Thus, each response to this questionnaire becomes very important to this research effort.

3. Questionnaire results should be returned to LT Jacoby via the pre-addressed envelope enclosed. Given the time constraints imposed by a March 1977 graduation date, completion of the questionnaire at your earliest convenience would greatly aid the research.

4. Your participation in this research project would be most appreciated.

J.S. Kolodziej
J.S. KOLODZIEJ

SEA DENIAL CAPABILITIES QUESTIONNAIRE

The proliferation of sophisticated anti-ship missile systems and modern small combatant platforms for these systems has caused increasing concern among naval planners. The demand for these relatively inexpensive weapons systems and the ability of lesser developed nations to effectively employ these platforms is likely to expand. The naval threat from lesser developed nations is likely to expand accordingly.

Research being conducted by LT Lowell E. Jacoby at the Naval Postgraduate School is attempting to evaluate the military worth of these weapons systems in order to better identify the threat that these systems pose. In this questionnaire you will be asked to evaluate various performance characteristics of surface-to-surface missiles and/or small surface combatants which typically are associated with these missiles in lesser developed nations' navies. The results from this questionnaire will provide an important input for an evaluation of the military capabilities of these modern naval systems.

Scenarios

Two scenarios are of particular concern in considering the implications of the transfer of anti-ship missiles and small surface combatants to lesser developed nations. Scenario #1 involves the possibility of guerrilla-type operations against merchant ships/tankers or surprise attacks against isolated surface combatants. Inherent in this scenario is the requirement that the missile platform transit to normal sea lanes/open ocean operating areas to conduct the attack. It is assumed that the attack would occur at the time and place of the missile boat commander's choice in conditions most favorable to the missile platform, and that the engagement would occur out of range of land or sea-based air cover.

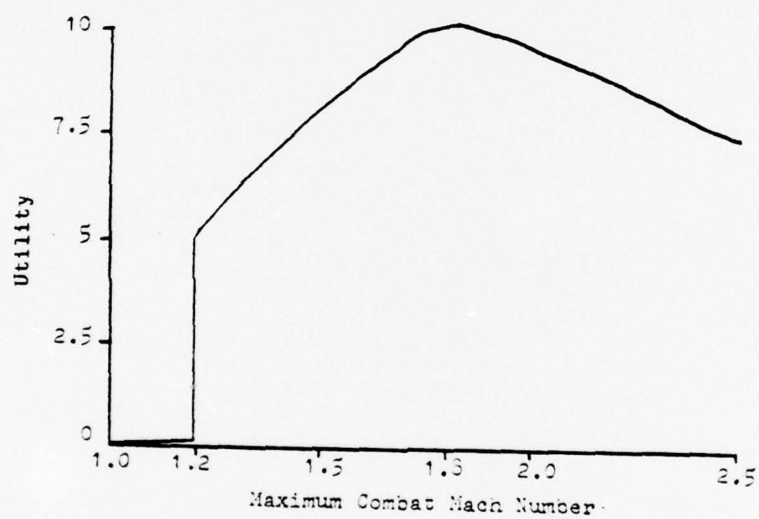
The other scenario (Scenario #2) concerns the possibility of missile platform vs missile platform war-at-sea between two or more lesser developed nations. This scenario matches the platforms in one-on-one engagements and assumes that neither opponent would have air support. The scenario is modeled upon confrontations such as

occurred during the 1970 Indo-Pakistani War and naval battles fought during the 1973 October War in the Middle East.

Example

The methodology being utilized in this research is termed "Multi-Attribute Utility Theory (MAUT)". MAUT requires the development of utility curves which serve as standards against which real-world systems can be judged. The following utility curve drawn from a study of air combat capabilities will serve as an illustration of the technique.

Utility Curve of Speed



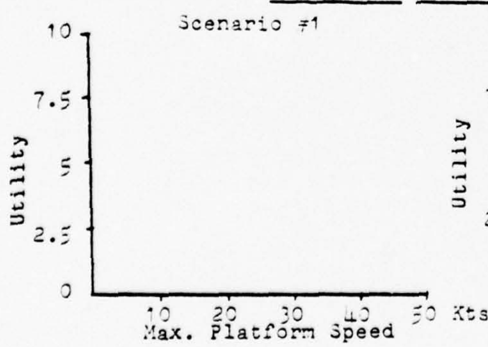
Interpretation: Judges evaluating Maximum Combat Mach Number indicate that a fighter's utility is minimal below a maximum Mach number of 1.2 and that utility increases steadily between Mach numbers of 1.2 and 1.8. At Mach 1.8 speed is optimal (represented by a score of 10) and utility decreases at speeds in excess of Mach 1.8. Given this curve, an aircraft with a maximum Mach number of 1.8 is twice as useful as a fighter as one with a 1.2 maximum. Also, an aircraft with a maximum combat Mach number of 1.5 would have a utility score of 8 for this characteristic.

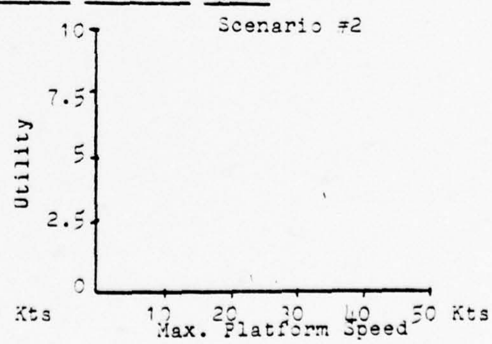
Questionnaire Instructions

You are asked to answer questions and sketch utility curves for the following characteristics associated with naval surface-to-surface missile systems or naval missile platforms. If you do not feel qualified to judge a particular characteristic, it should not preclude you from answering other questions, since each is considered to be independent of all other questions. In each case a utility score of zero represents the minimum for a particular characteristic necessary for successful performance of the mission outlined in each scenario. (Example: The judges felt that below 1.0 Mach an aircraft does not have sufficient speed to successfully perform the air combat mission.) A utility score of ten represents the upper limit; ie. what you judge to be technologically feasible or desirable, to perform the mission outlined in each scenario. (Example: 1.8 Mach represents the speed the judges felt was most desirable in an air combat environment.) At the end of the questionnaire you are asked to weight those factors which you judged. It should be emphasized that you are being asked for subjective judgments based on your experience at all times in filling out this questionnaire.

1. What designated maximum platform speed is most desirable (Utility score of ten) for a naval missile platform performing the mission outlined in Scenario #1 ________; Scenario #2 ________? What is the lowest designated maximum platform speed (Utility of zero) required for successful performance of Scenario #1 missions ________; Scenario #2 missions ________? Please sketch the two curves in the spaces below.

Designated Maximum Platform Speed

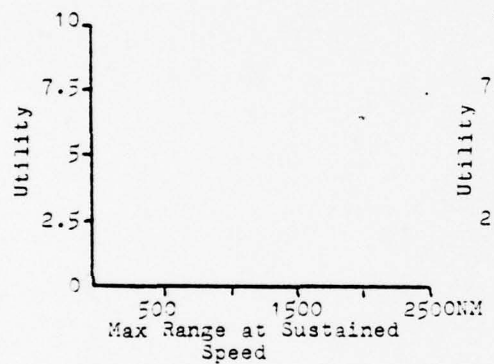




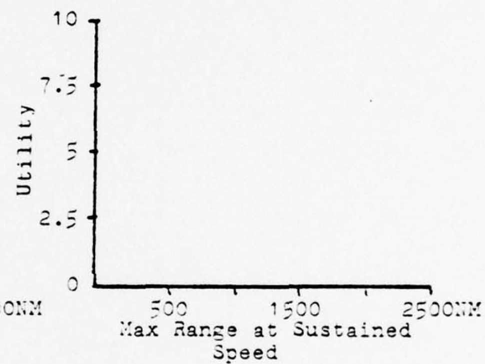
2. Given the necessary trade-offs between platform size, fuel capacity, fuel consumption at maximum speed vs fuel consumption at economical speed, etc., what range at maximum sustained speed is most desirable (Utility score of ten) for a missile platform performing the mission outlined in Scenario #1 ________; Scenario #2 ________? What is the least range at maximum sustained speed (Utility score of zero) required for successful performance of the Scenario #1 mission ________; Scenario #2 mission ________? Please sketch the two curves in the spaces below.

Range at Maximum Sustained Speed

Scenario #1



Scenario #2

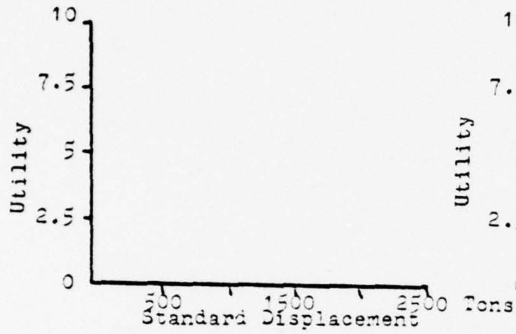


3. Many of the lesser developed nations face money constraints in purchasing naval missile platforms. This makes the cost per unit and considerations of the number of units which are desirable given the flexibility/survivability which accompanies larger numbers of units of prime concern in purchasing decisions. Given these considerations and the trade-offs which exist between stability, detectability, space for sensors and weapons systems, etc., what standard displacement is most desirable (Utility score of ten) for missile platforms performing the mission outlined in Scenario #1 ________; Scenario #2 ________? What is the minimum standard displacement required (Utility score of zero) for missile platforms performing the Scenario #1 mission ________; Scenario #2 mission ________?

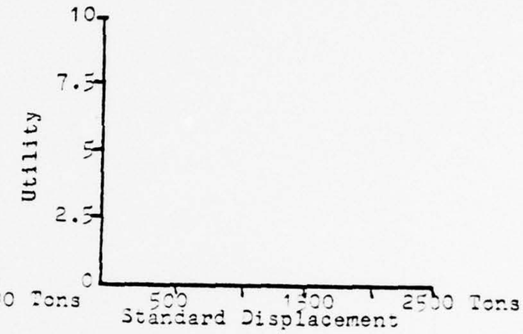
Please sketch the two curves for standard displacement in the spaces provided below.

Standard Displacement

Scenario #1



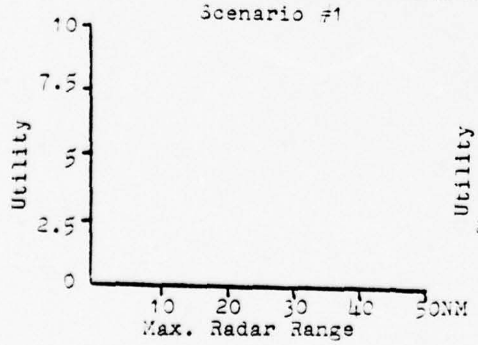
Scenario #2



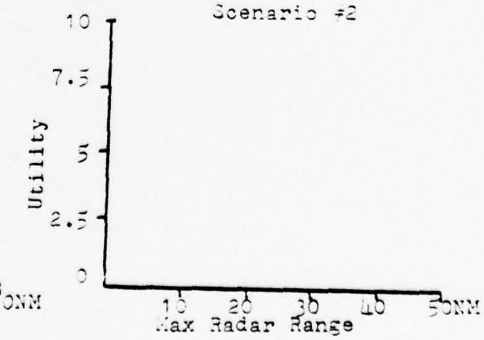
4. Given the fact that most of the missile platforms under consideration are limited in internal space and height of tallest mast, what is the maximum radar acquisition range (Utility of ten) which is desirable/technologically feasible for platforms operating against merchant ship/tanker-size targets in Scenario #1 missions ________; against missile patrol boat-size targets in Scenario #2 ________? What is the shortest maximum radar acquisition range (Utility score of zero) possible which will permit successful accomplishment of the mission outlined in Scenario #1 ________ (merchant ship/tanker-size target); Scenario #2 ________ (missile patrol boat-size target)? Please sketch the two curves in the spaces below.

Maximum Radar Acquisition Range

Scenario #1



Scenario #2



5. Given trade-offs involving limited space and desire for additional weapons systems, etc., what utility scores would you attach to the following ECM capabilities for platforms involved in missions outlined in the two scenarios (Utility scores range from a high of ten to a low of zero)?

	Scenario #1	Scenario #2
a. Chaff dispenser	________	________
b. Broad-band jammer	________	________
c. Spot jammer	________	________
d. Chaff plus broad-band jammer	________	________
e. Chaff plus spot jammer	________	________
f. Broad-band and spot jammer	________	________
g. Chaff, broad-band and spot jammers	________	________

6. As was noted in Question 3, there are a number of factors which tend to limit the size of missile platforms operated by lesser developed nations. Given space limitations and the fact that including anti-ship missile defense weapons might require the removal of some surface-to-surface missile launchers, what utility scores would you attach to the following anti-ship missile defense systems for platforms involved in missions outlined in Scenario #2? (Utility scores range from a high of ten to a low of zero.)

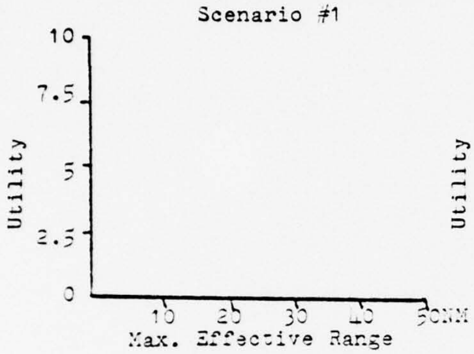
	Score
a. AAA gun (23mm to 30mm range)	____
b. Gatling gun	____
c. Point defense SAM system	____
d. AAA gun and point defense SAM system	____
e. Gatling gun and point defense SAM system	____
f. AAA gun and Gatling gun	____
g. AAA gun, Gatling gun and point defense SAM system	____

7. Realizing that there are size, weight, warhead size, guidance considerations, etc., what is the maximum effective range of the missile (Utility of ten) which is most desirable/technologically feasible for the performance of the Scenario #1 mission ________; the Scenario #2 mission ________? What is the lowest maximum effective range of the missile which would permit successful completion

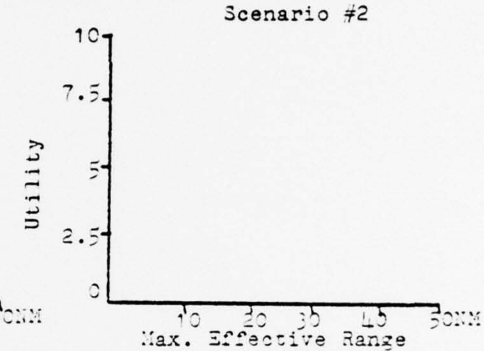
of the mission outlined in Scenario #1 ________; outlined in Scenario #2 ________? Please sketch the two curves in the spaces below.

Maximum Effective Range of the Missile

Scenario #1



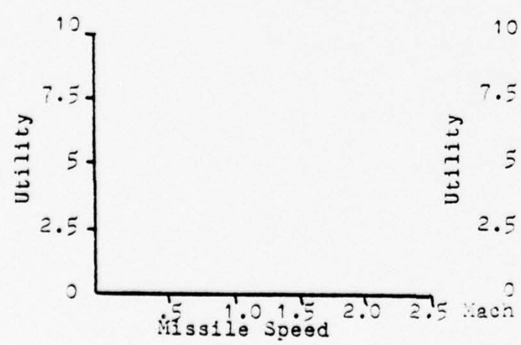
Scenario #2



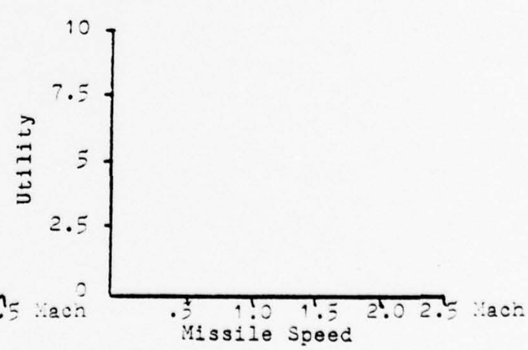
8. Given the trade-offs between penetration capability, missile range, warhead size, etc., what missile speed is most desirable/technologically feasible (Utility score of ten) for a naval missile performing the mission outlined in Scenario #1 ________; outlined in Scenario #2 ________? What is the minimum missile speed required (Utility of zero) for successful execution of the Scenario #1 mission ________; Scenario #2 ________? Please sketch the two curves in the spaces below.

Missile Speed

Scenario #1

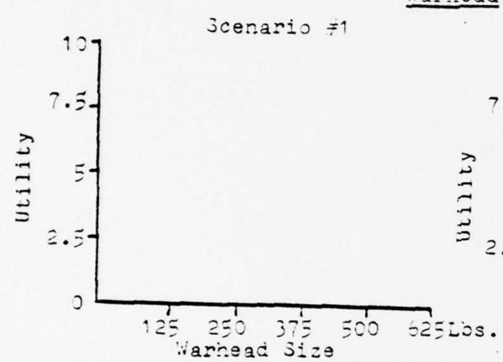


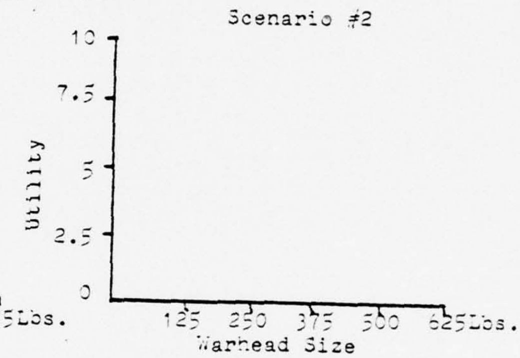
Scenario #2



9. Given trade-offs between missile size, range, weight, etc., what is the maximum warhead size desirable/technologically feasible (Utility of ten) for a naval missile performing Scenario #1 missions ________; Scenario #2 missions ________? What is the minimum warhead size which will allow successful completion (Utility of zero) of the mission outlined in Scenario #1 ________; Scenario #2 ______? Please sketch the two curves in the spaces below.

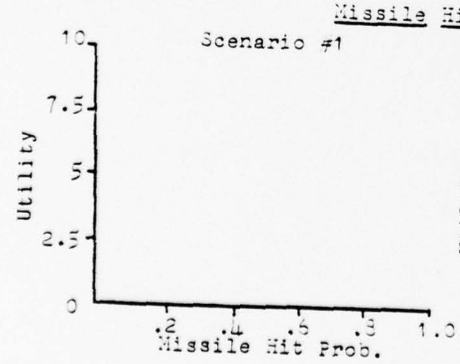
Warhead Size

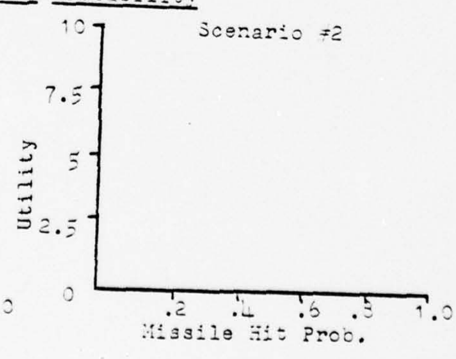




10. The maximum missile hit probability which is desirable/technologically feasible is clearly one. What is the minimum missile hit probability which you feel is acceptable in performing the mission outlined in Scenario #1 ________? Ignoring the problem of probability of penetration, what is the minimum missile probability acceptable in performing the mission outlined in Scenario #2 ________? Please sketch the two curves in the spaces below. (Utility of ten is assigned to missile hit probability of one.)

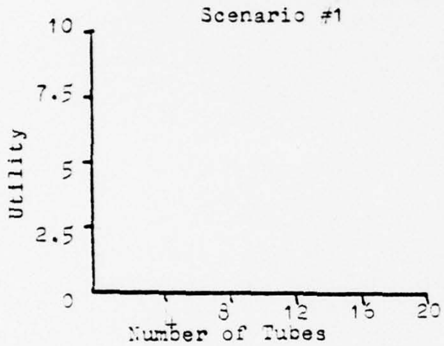
Missile Hit Probability

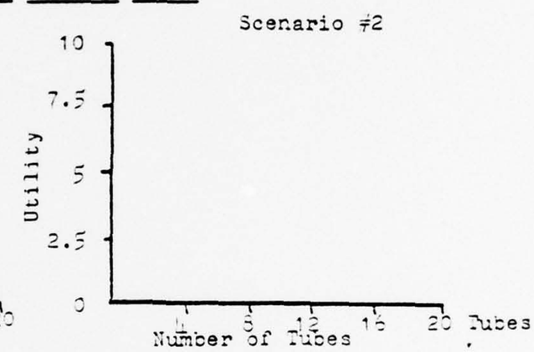




11. Given the trade-offs with size, hit probability, etc., and the desirability to launch multiple missiles in certain scenarios, plus limitations imposed by the missile control mechanisms, what is the optimal number of missile tubes (Utility of ten) to have on the launch platform to perform the mission outlined in Scenario #1 ________; Scenario #2 ________? What is the minimum number of missile tubes required for successful completion of the Scenario #1 mission ________; Scenario #2 mission ________? Please sketch the utility curves in the spaces below.

Number of Missile Tubes





12. What utility scores would you attach to the following missile guidance systems given the requirements of the missions outlined in the two scenarios? (Utility scores range from a high of ten to a low of zero.)

	Scenario #1	Scenario #2
a. Inertial with active radar terminal guidance	________	________
b. Autopilot with active radar terminal guidance	________	________
c. Command with active radar terminal guidance	________	________
d. Command with semi-active radar terminal guidance	________	________
e. Beam rider	________	________

	Scenario #1	Scenario #2
f. Active radar	________	________
g. Anti-radiation homing	________	________
h. Wire guided	________	________

13. What utility score would you assign (Utility scores range from a maximum of ten to a minimum of zero) to a missile with a home-on-jam capability given Scenario #1 ________; given Scenario #2 ________?

14. What utility scores would you assign to the following fuzing configurations given the requirements of the missions outlined in the two scenarios? (Utility scores range from a maximum of ten to a minimum of zero.)

	Scenario #1	Scenario #2
a. Contact fuze	________	________
b. Contact with delay	________	________
c. Proximity fuze	________	________

15. With the wide variety of performance characteristics covered in this questionnaire, it is probable that not all of the characteristics contribute equally to mission success. In the spaces below indicate the weighting factor which should be applied to each characteristic based on that characteristic's contribution to successful completion of the missions outlined in the two scenarios. If you feel that two or more characteristics are equally important to successful completion, they should be assigned the same weighting factor. Weightings range from zero, which means that the factor makes no contribution to successful mission completion, to ten, which means that the characteristic plays an essential role in successful completion of the mission outlined. Please weight only those factors which you judged in the previous sections of the questionnaire.

	Scenario #1	Scenario #2
1. Designated maximum platform speed	________	________
2. Platform range at maximum sustained speed	________	________

	Scenario #1	Scenario #2
3. Standard platform displacement	________	________
4. Maximum radar acquisition range	________	________
5. Platform ECM capabilities	________	________
6. Anti-ship missile defense systems	________	________
7. Maximum effective range of the missile	________	________
8. Missile speed	________	________
9. Warhead size	________	________
10. Missile hit probability	________	________
11. Number of missile tubes	________	________
12. Type of missile guidance system	________	________
13. Home-on-jam capability	________	________
14. Fuzing configuration	________	________

16. A lesser developed nation's capacity to provide qualified crews and to maintain the weapons systems is of concern in attempting to evaluate the military worth of the anti-ship missile systems and modern small combatant platforms found in their inventory. Please provide your evaluation of the relative importance of the human factors and the platform performance characteristics of these systems in performing the missions outlined in the two scenarios. Scores range from a high of ten to a low of zero. Ten indicates that the factor is all important to mission success. A score of zero indicates that the factor has no importance in performing the mission successfully. Duplicate scores can be awarded if you feel that the two factors have equal importance.

	Scenario #1	Scenario #2
a. Human factors--capability to man, maintain and operate the overall weapons system.	________	________
b. Performance factors--overall performance capabilities of the weapons system.	________	________

Any comments which you would like to include on the back of this page would be greatly appreciated. Again, thank you very much for the time and effort put into completion of this questionnaire.

APPENDIX C

TORPEDO-FIRING DIESEL SUBMARINE QUESTIONNAIRE

NAVAL POSTGRADUATE SCHOOL
Monterey, California

From: Curricular Officer, Naval Intelligence Curriculum (Code-38)
To:

Subj: Student Questionnaire; distribution of

Encl: (1) Diesel Submarine Capabilities Questionnaire

1. Enclosure 1 represents one part of a student research project currently underway at the Naval Postgraduate School designed to measure the military worth of torpedo-firing diesel submarines found in the inventories of various lesser developed nations. Results of this questionnaire will be incorporated into a thesis being prepared by LT Lowell E. Jacoby as a degree requirement in the Naval Intelligence Curriculum.

2. Distribution of this questionnaire has been greatly constrained by the shortage of personnel within the U.S. Navy structure with analytical expertise and/or recent operational experience with diesel submarines. Thus, each response to this questionnaire becomes very important to this research effort.

3. Questionnaire results should be returned to LT Jacoby via the pre-addressed envelope enclosed. Given the time constraints imposed by a March 1977 graduation date, completion of the questionnaire at your earliest convenience would greatly aid the research project.

4. Your participation in this research project would be most appreciated.

J S Kolodziej
J. S. KOLODZIEJ

DIESEL SUBMARINE CAPABILITIES QUESTIONNAIRE

The increase in the numbers of diesel submarines in lesser developed nations' inventories and the increase in numbers of nations possessing torpedo-firing diesel submarines in recent years has caused increasing concern among naval planners. The demand for submarines and the ability of lesser developed nations to effectively employ these platforms is likely to expand. The naval threat from lesser developed nations is likely to expand accordingly.

Research being conducted by LT Lowell E. Jacoby at the Naval Postgraduate School is attempting to evaluate the military worth of these weapons systems in order to better identify the threat that these systems pose. In this questionnaire you will be asked to evaluate various performance characteristics of torpedo-firing diesel submarines. The results from this questionnaire will provide an important input for an evaluation of the military capabilities of these naval weapons systems.

<u>Scenarios</u>

Two scenarios are of particular concern in considering the implications of the transfer of torpedo-firing diesel submarines to lesser developed nations. <u>Scenario #1</u> involves the possibility of guerrilla-type operations against merchant ships/tankers or surprise attacks against isolated surface combatants. Inherent in this scenario is the requirement that the attacking submarine transit to normal sea lanes to conduct the attack. It is assumed that the attack would occur at the time and place of the submarine commander's choice in conditions most favorable to the attacking unit, and that the entire attack phase of the scenario would occur out of range of land or sea-based surveillance and/or ASW aircraft.

The other scenario (<u>Scenario #2</u>) concerns the possibility that diesel submarines would be used in a war-at-sea between two or more lesser developed nations. It is assumed that the submarines would be employed against the other nation's surface combatants in this circumstance. These ships generally have a limited ASW capability. The surface combatants are assumed to be alert to the submarine

threat posed by the adversary, but are unable to call upon sea or land-based air support.

Example

The methodology being utilized in this research is termed "Multi-Attribute Utility Theory (MAUT)." MAUT requires the development of utility curves which serve as standards against which real-world systems can be judged. The following utility curve drawn from a study of air combat capacilities will serve as an illustration of the technique.

Utility Curve of Speed

Interpretation: Judges evaluating Maximum Combat Mach Number indicate that a fighter's utility is minimal below a maximum Mach number of 1.2 and that utility increases steadily between Mach numbers of 1.2 and 1.8. At Mach 1.8 speed is optimal (represented by a score of 10) and utility decreases at speeds in excess of Mach 1.8. Given this curve, an aircraft with a maximum Mach number of 1.8 is twice as useful as a fighter as one with a 1.2 maximum. Also, an aircraft with a maximum combat Mach number of 1.5 would have a utility score of 8 for this characteristic.

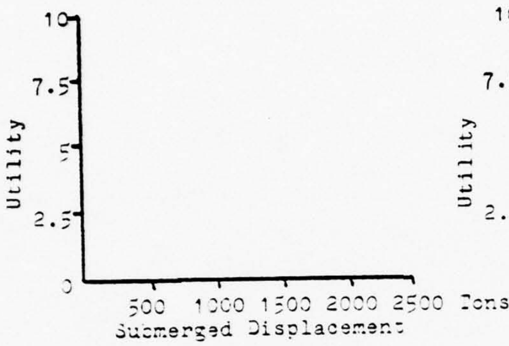
Questionnaire Instructions

You are asked to answer questions and sketch utility curves for the following characteristics associated with naval surface-to-surface missile systems or naval missile platforms. If you do not feel qualified to judge a particular characteristic, it should not preclude you from answering other questions, since each is considered to be independent of all other questions. In each case a utility score of zero represents the minimum for a particular characteristic necessary for successful performance of the mission outlined in each scenario. (Example: The judges felt that below 1.0 Mach an aircraft does not have sufficient speed to successfully perform the air combat mission.) A utility score of ten represents the upper limit; ie. what you judge to be technologically feasible or desirable, to perform the mission outlined in each scenario. (Example: 1.8 Mach represents the speed the judges felt was most desirable in an air combat environment.) At the end of the questionnaire you are asked to weight those factors which you judged. It should be emphasized that you are being asked for subjective judgments based on your experience at all times in filling out this questionnaire.

1. Many of the lesser developed nations face money constraints in purchasing submarines. This makes cost per unit and considerations concerning the number of units which are desirable given the increased flexibility/survivability which accompanies larger numbers of units of prime concern in purchasing decisions. Given these trade-offs, what submerged displacement is most desirable (Utility of ten) for a submarine performing the mission outlined in Scenario #1 ________; Scenario #2 ________? What is the minimum submerged displacement required (Utility of zero) for submarines to successfully perform the Scenario #1 mission ________; the Scenario #2 mission ________? Please sketch the two curves in the spaces provided on the next page.

Submerged Displacement

Scenario #1

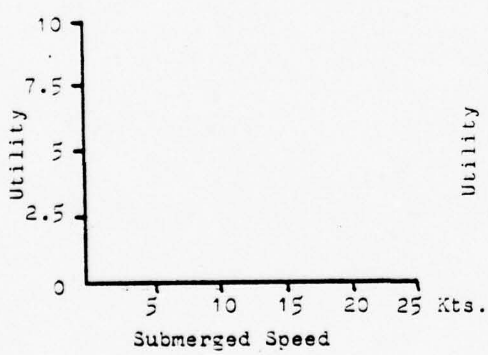


Scenario #2

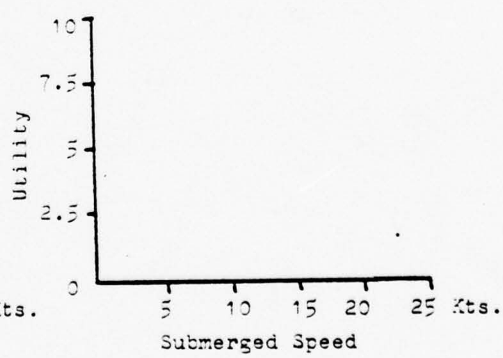
2. What maximum submerged speed is most desirable (Utility score of ten) for a submarine performing the mission outlined in Scenario #1 ________; Scenario #2 ________? What is the lowest maximum submerged speed (Utility of zero) required for successful performance of Scenario #1 missions ________; Scenario #2 missions ________? Please sketch the two curves in the spaces below.

Submerged Speed

Scenario #1



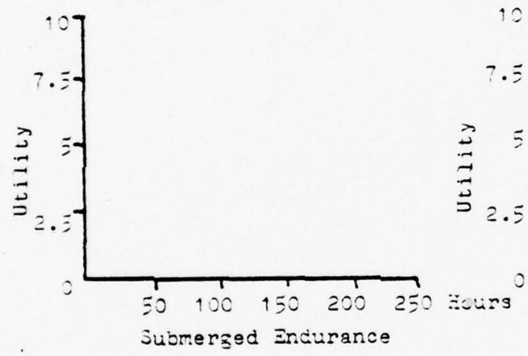
Scenario #2



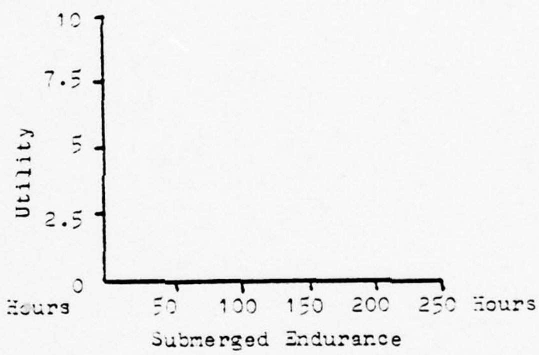
3. Given the trade-offs between size, power drain by internal equipment, battery size limitations, etc., and assuming that the submarine will have to transit to the operating area, localize and attack the target without anything but the most general targeting data, what is the maximum submerged endurance desirable/technologically feasible (Utility of ten) for the mission outlined in Scenario #1 ________; Scenario #2 ________? What is the lowest submerged endurance (Utility of zero) required for successful performance of the Scenario #1 mission ________; the Scenario #2 mission ________? Please sketch the two curves in the spaces below.

Submerged Endurance

Scenario #1



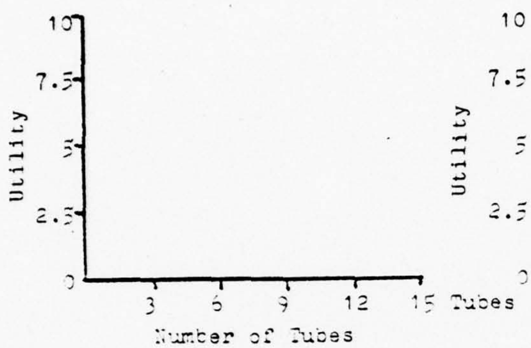
Scenario #2



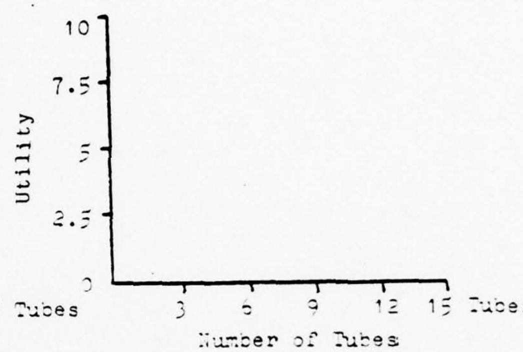
4. Given the trade-offs in platform size, hit probability, platform cost, and the desirability of launching multiple torpedoes in certain circumstances to increase the chances of multiple hits on the target, what number of torpedo tubes would be optimal (Utility of ten) for performance of the mission outlined in Scenario #1 ________; Scenario #2 ________? What is the minimum number of torpedo tubes required for successful completion of the Scenario #1 mission ________; the Scenario #2 mission ________? Please sketch the two curves in the spaces on the next page.

Number of Torpedo Tubes

Scenario #1



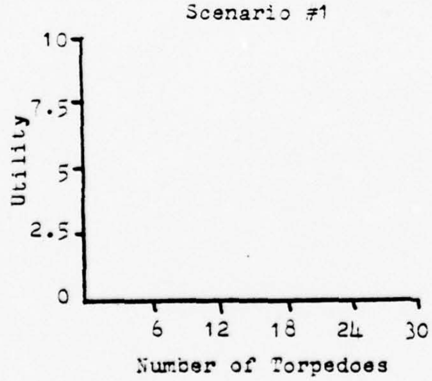
Scenario #2



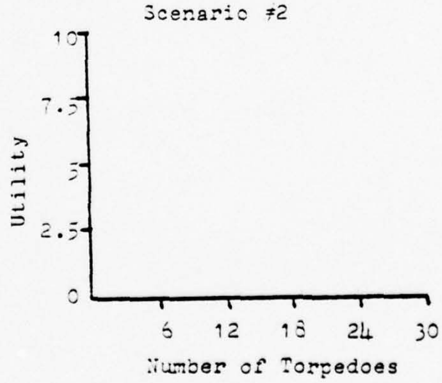
5. Given platform size, amount of stowage space, etc., trade-offs, what is the optimal number of torpedoes (Utility of ten) to carry on-board a submarine performing the Scenario #1 mission ________; the Scenario #2 mission ________? What is the lowest number of torpedoes (Utility of zero) which can be carried and still successfully perform the Scenario #1 mission ________; the Scenario #2 mission ________? Please sketch the two curves in the spaces below.

Number of Torpedoes

Scenario #1



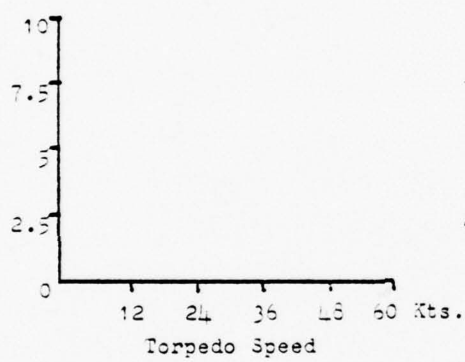
Scenario #2



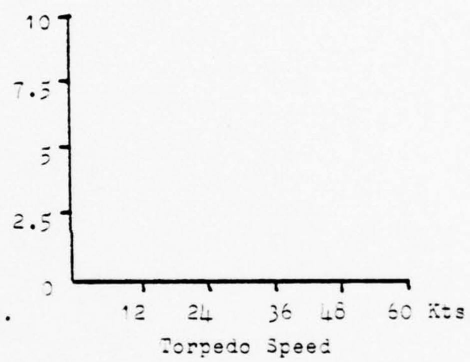
6. Given the trade-offs between penetration capability, range, accuracy, etc., what torpedo speed is optimal (Utility of ten) given the Scenario #1 mission ________; the Scenario #2 mission ________? What is the minimum torpedo speed required (Utility of zero) for successful execution of the mission outlined in Scenario #1 ________; Scenario #2 ________? Please sketch the two curves in the spaces below.

Torpedo Speed

Scenario #1

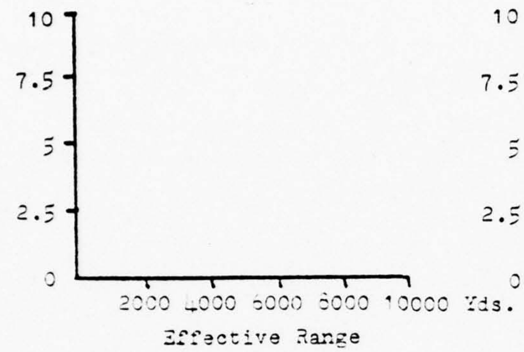


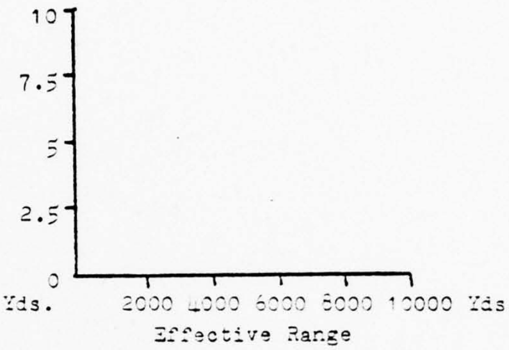
Scenario #2



7. Given accuracy and other trade-offs which enter into range considerations, what is the maximum effective range of the torpedo (Utility of ten) which is most desirable/technologically feasible for the performance of the Scenario #1 mission ________; the Scenario #2 mission ________? What is the minimum effective range of the torpedo which would permit successful completion of the mission outlined in Scenario #1 ________; Scenario #2 ________? Please sketch the two curves in the spaces provided on the next page.

Effective Range of the Torpedo





8. What utility scores would you attach to the following torpedo guidance systems given the requirements of the missions outlined in the two scenarios? (Utility scores range from a high of ten to a low of zero.)

	Scenario #1	Scenario #2
a. Anti-surface/non-electric "Steam-fish"	________	________
b. Acoustic	________	________
c. Wire-guided	________	________

9. Assuming that the submarine will have to localize and attack the target without anything more than the most general information from outside sources to support the attack, what utility scores would you attach to the following acquisition techniques in operations against merchant ship/tanker-sized targets in Scenario #1 and against combatant-sized targets in Scenario #2? (Utility scores range from a high of ten to a low of zero.)

	Scenario #1	Scenario #2
a. Visual	________	________
b. Active sonar	________	________
c. Passive sonar	________	________
d. Active and passive sonars	________	________

10. Given the fact that a submarine's ESM capability can be used as a detection/localization and verification tool, what utility score would you assign (Utility scores range from a maximum of ten to a minimum of zero) to a submarine with an ESM capability in Scenario #1 _______; in Senario #2 _______?

11. What utility score would you assign to a short range, submerged-launch anti-ship missile (SLAM) capability given the merchant ship/tanker target outlined in Scenario #1 _______; given the combatant target outlined in Scenario #2 _______?

12. With the wide variety of performance characteristics covered in this questionnaire, it is probable that not all of the characteristics contribute equally to mission success. In the spaces below indicate the weighting factor which should be applied to each characteristic based on that characteristic's contribution to successful completion of the missions outlined in the two scenarios. If you feel that two or more characteristics are equally important to successful completion, they should be assigned the same weighting factor. Weightings range from zero, which means that the factor makes no contribution to successful mission completion, to ten, which means that the characteristic plays an essential role in successful completion of the mission outlined. Please weight only those factors which you judged in the previous sections of the questionnaire.

	Scenario #1	Scenario #2
a. Submerged displacement	_______	_______
b. Submerged speed	_______	_______
c. Submerged endurance	_______	_______
d. Number of torpedo tubes	_______	_______
e. Number of torpedoes	_______	_______
f. Torpedo speed	_______	_______
g. Effective range of the torpedo	_______	_______
h. Torpedo guidance systems	_______	_______
i. Acquisition techniques	_______	_______
k. ESM capability	_______	_______
l. SLAM capability	_______	_______

13. A lesser developed nation's capacity to provide qualified crews and to maintain the weapons system is of concern in attempting to evaluate the military worth of the diesel submarines found in their inventory. Please provide your evaluation of the relative importance of the human factors and the platform's performance characteristics for diesel submarines performing the missions outlined in the two scenarios. Scores range from a high of ten to a low of zero. Ten indicates that the factor is all important to mission success. A score of zero indicates that the factor has no importance in performing the mission successfully. Duplicate scores can be awarded if you feel the two factors have equal importance.

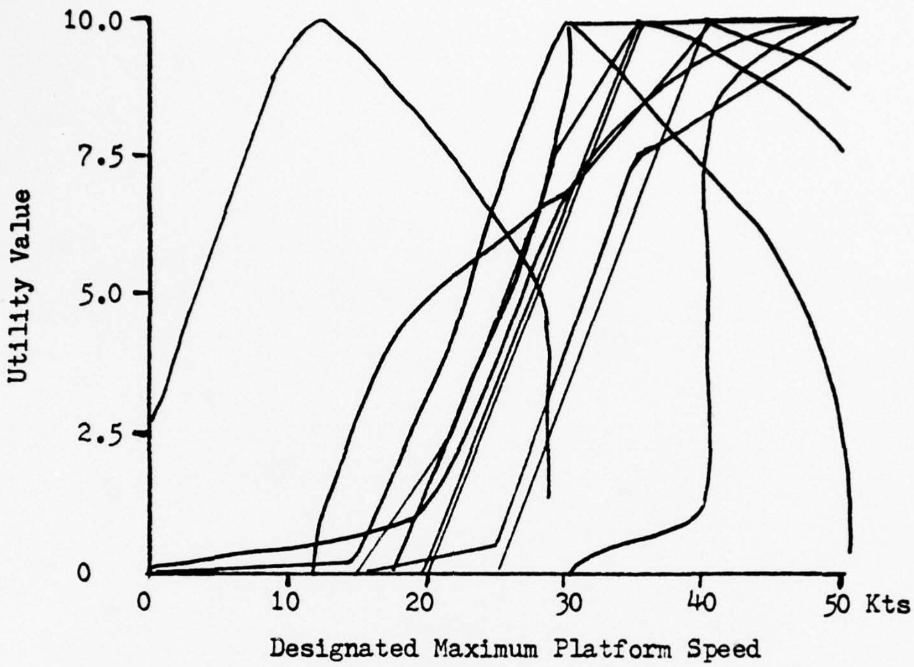
	Scenario #1	Scenario #2
a. Human factors--capability to man, maintain and operate the submarine.	______	______
b. Performance factors--overall performance capabilities of the weapons system.	______	______

Any comments which you would like to include in the space below would be greatly appreciated. Again, thank you very much for the time and effort put into completion of this questionnaire.

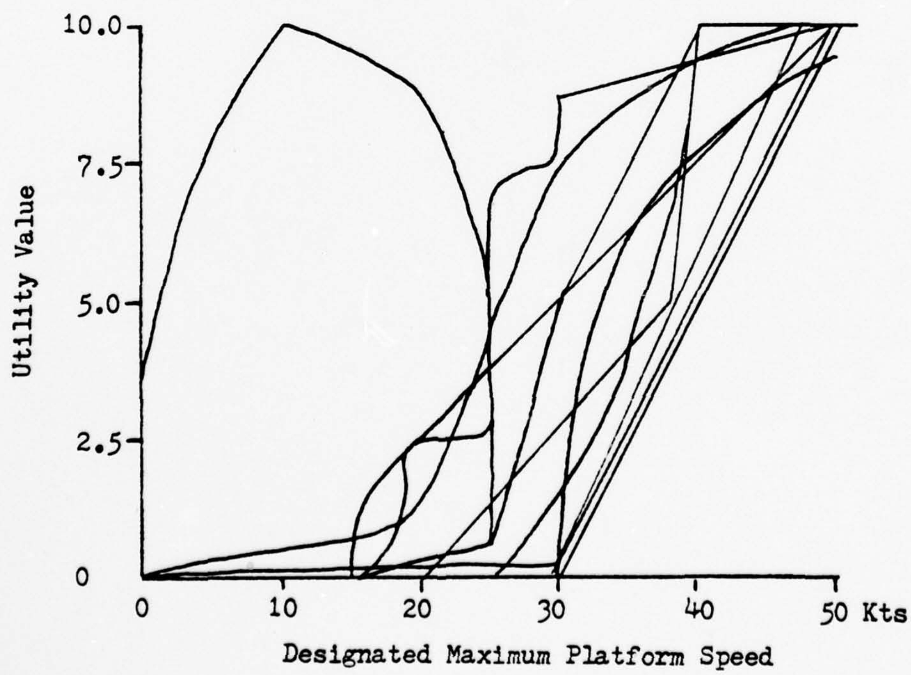
APPENDIX D

ANTISHIP MISSILE COMBATANT QUESTIONNAIRE RESULTS

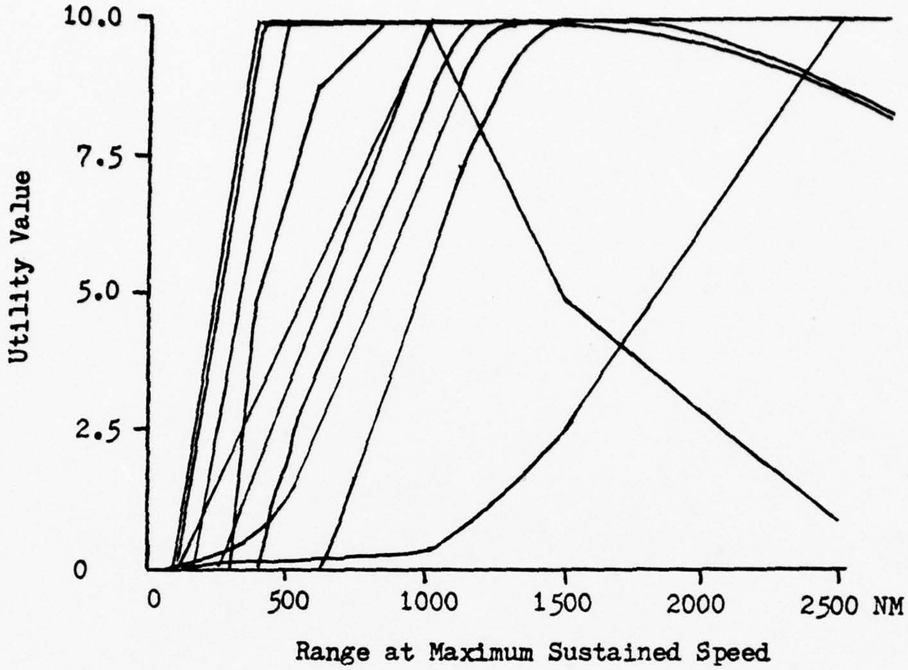
DESIGNATED MAXIMUM PLATFORM SPEED (SCENARIO #1)



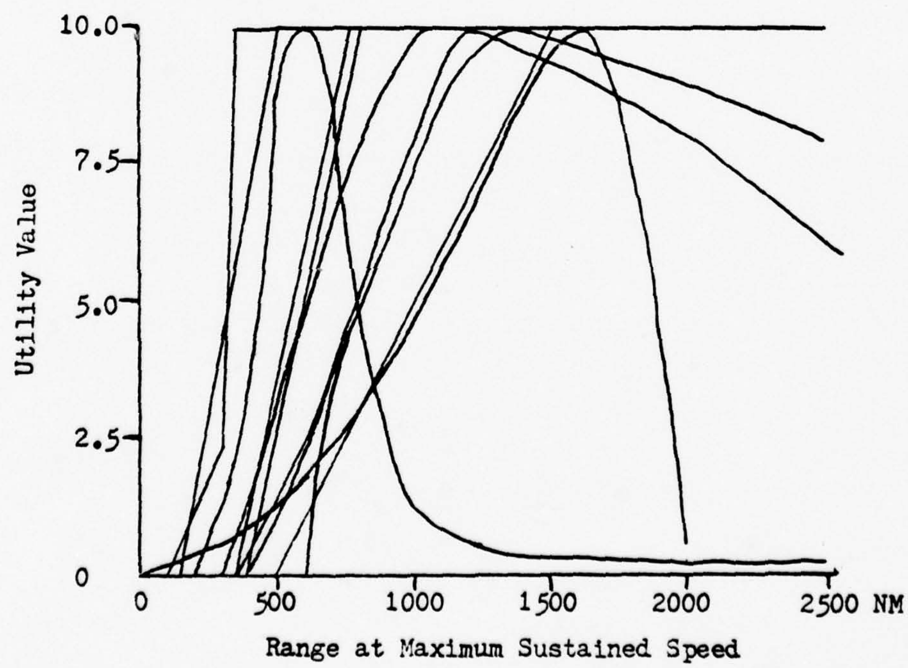
DESIGNATED MAXIMUM PLATFORM SPEED (SCENARIO #2)



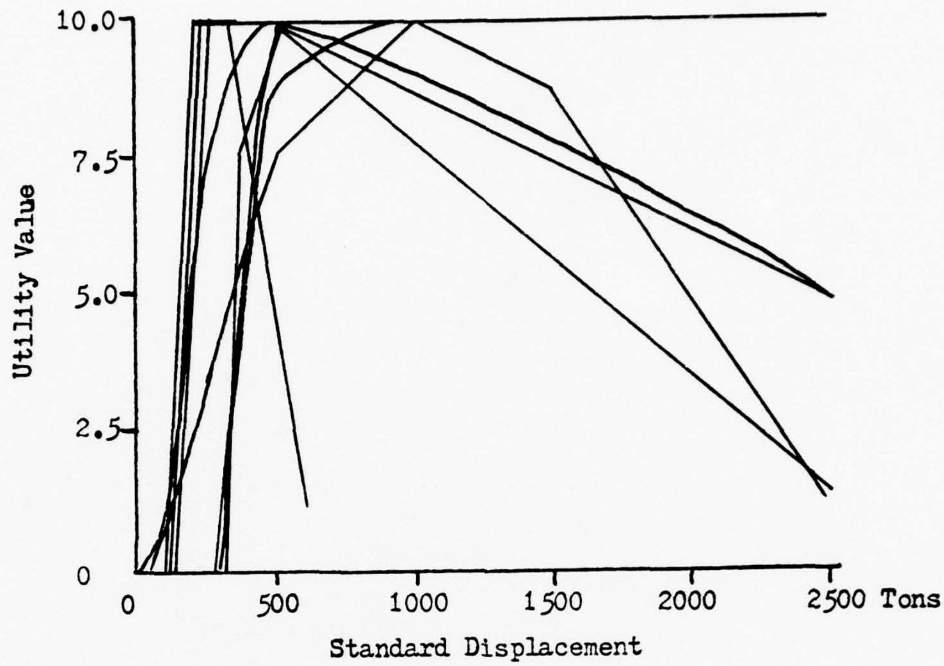
RANGE AT MAXIMUM SUSTAINED SPEED (SCENARIO #1)



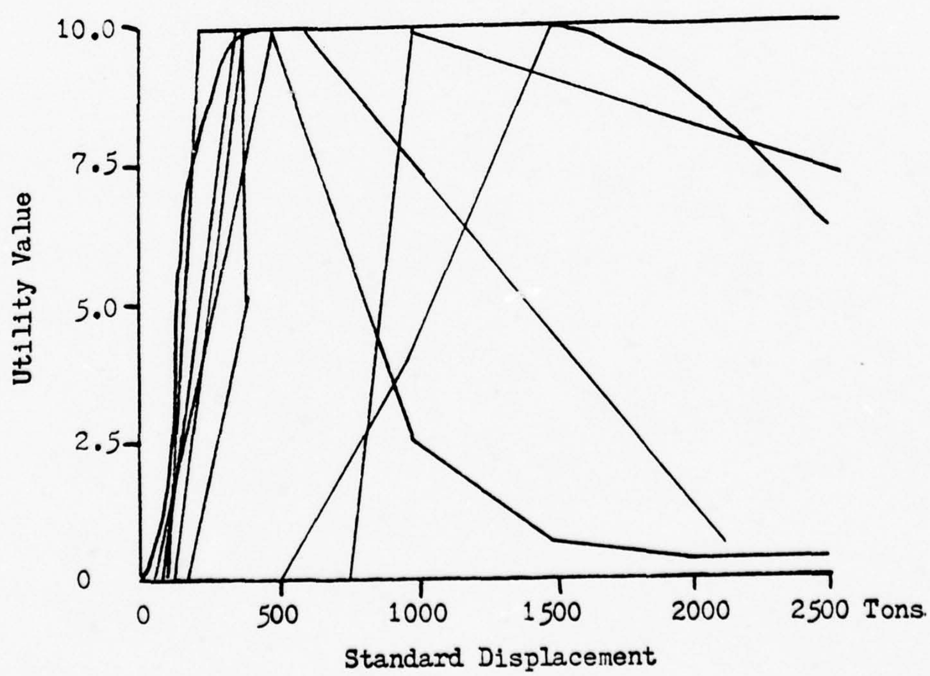
RANGE AT MAXIMUM SUSTAINED SPEED (SCENARIO #2)



STANDARD DISPLACEMENT (SCENARIO #1)



STANDARD DISPLACEMENT (SCENARIO #2)



ECM CAPABILITIES (SCENARIO #1)

	Judges' Scores									
	#1	#2	#3	#4	#5	#6	#7	#8	#9	Average Score
Chaff Dispenser	5	0	0	7	0	10	2	2	0	2.9
Broad-band Jammer	5	0	0	3	10	6			10	4.9
Spot Jammer	3	0	0	5	7	0			4	2.7
Chaff plus Broad-band Jammer	5	0	0	8	0	0			7	2.9
Chaff plus Spot Jammer	5	0	0	9	0	0			4	2.6
Broad-band and Spot Jammer	5	0	0	6	10	0			7	4.0
Chaff, Broad-band and Spot Jammers	5	0	0	10	7	0			7	4.1

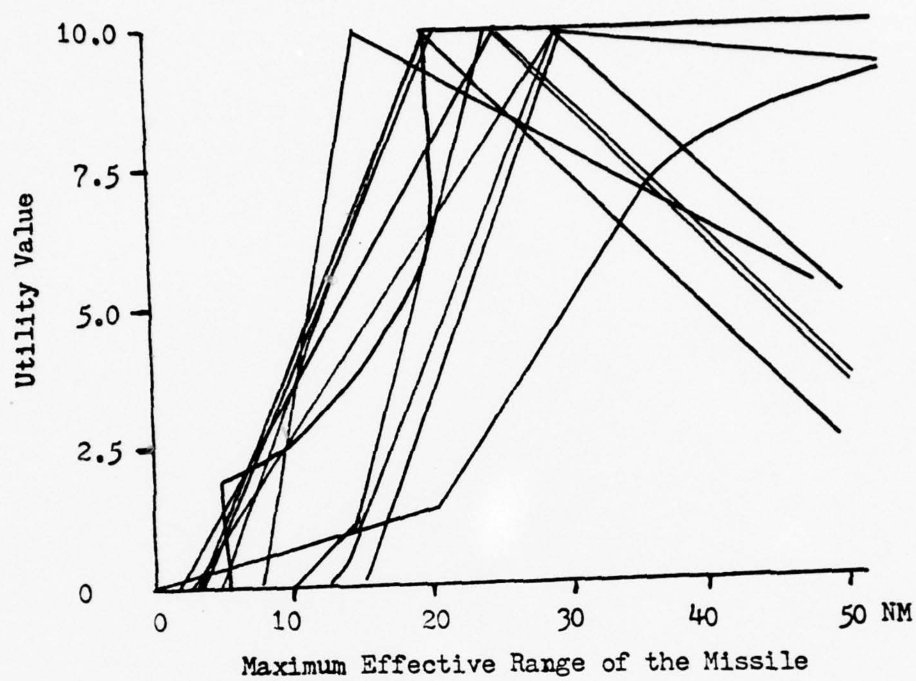
ECM CAPABILITIES (SCENARIO #2)

Chaff Dispenser	10	0	2	7	0	6	10	10	9	6.0
Broad-band Jammer	10	4	2	2	10	4			2	4.9
Spot Jammer	8	9	1	6	7	3			0	4.9
Chaff plus Broad-band Jammer	10	4	2	8	0	8			8	5.7
Chaff plus Spot Jammer	8	9	2	10	0	7			6	6.0
Broad-band and Spot Jammer	10	10	2	6	10	5			3	6.6
Chaff, Broad-band and Spot Jammers	10	10	2	9	7	10			10	8.3

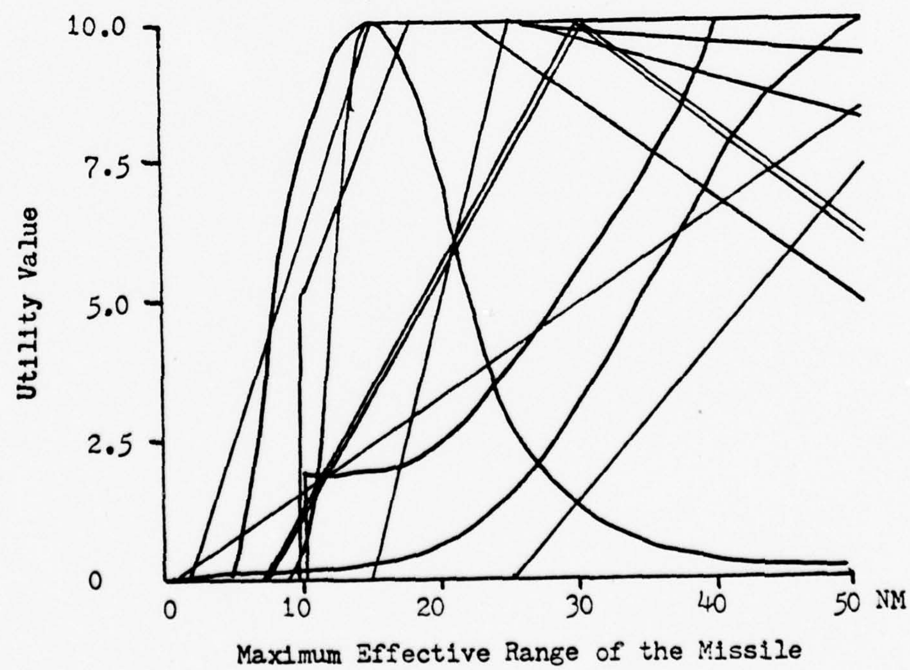
ANTI-SHIP MISSILE DEFENSE SYSTEM (SCENARIO #2 ONLY)

	Judges' Scores									
	#1	#2	#3	#4	#5	#6	#7	#8	#9	Average Score
AAA Gun	1	2	6	7	0	4	8	8	1	4.1
Gatling Gun	5	6	2	10	10	5	10	10	6	7.1
Point Defense SAM	7	7	1	1	2	7	6	4	4	4.7
AAA Gun and Point Defense SAM	5	8	3	1	5	9	0	0	4	3.9
Gatling Gun and Point Defense SAM	9	10	2	1	10	8	0	0	10	5.6
AAA Gun and Gatling Gun	3	6	4	2	5	7	5	5	6	4.8
AAA Gun, Gatling Gun and Point Defense SAM	5	9	4	0	7	10	0	0	7	4.6

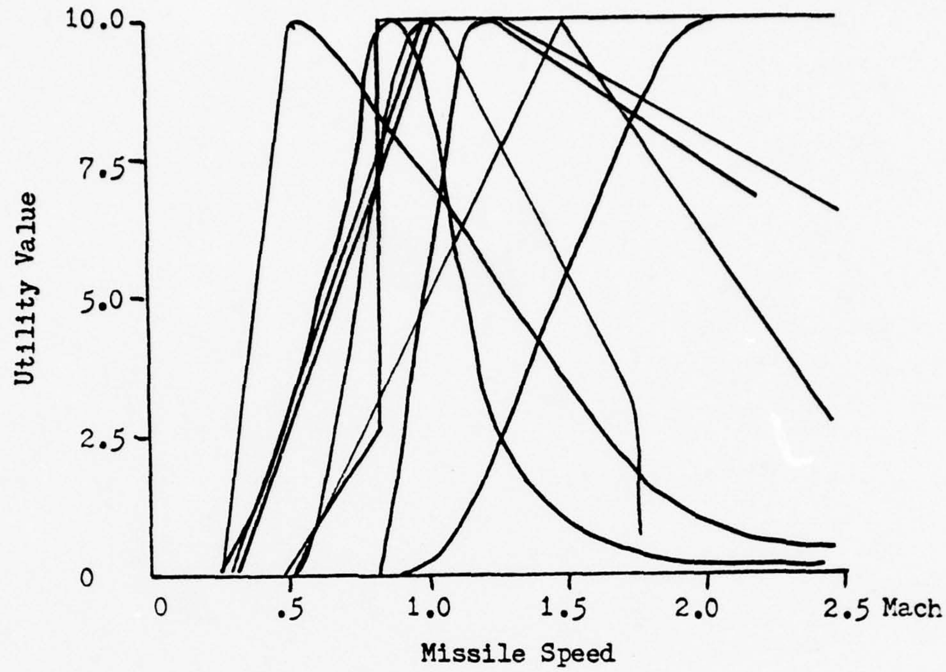
MAXIMUM EFFECTIVE RANGE OF THE MISSILE (SCENARIO #1)



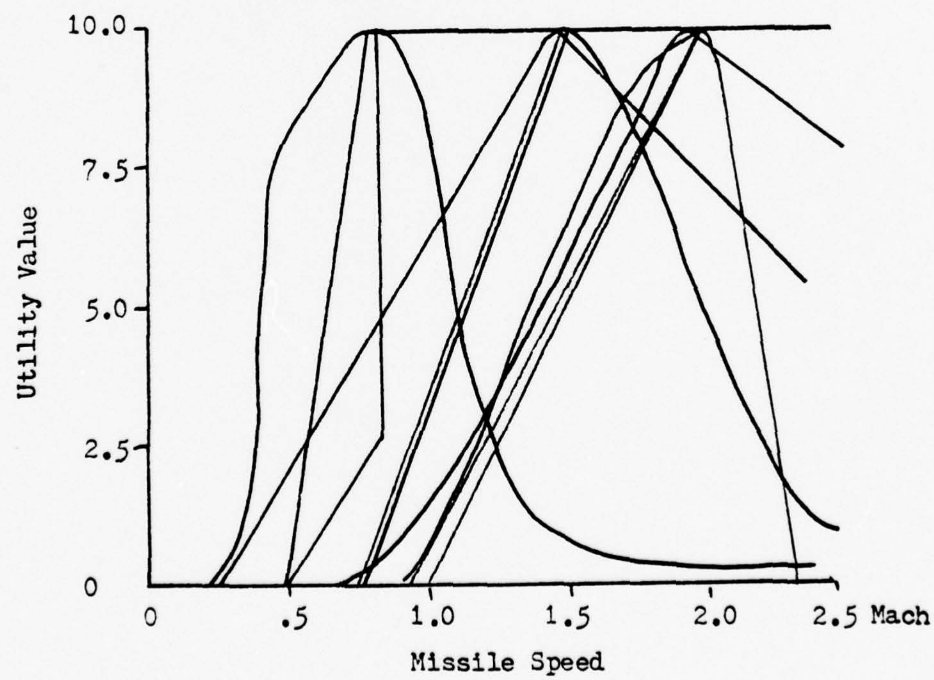
MAXIMUM EFFECTIVE RANGE OF THE MISSILE (SCENARIO #2)



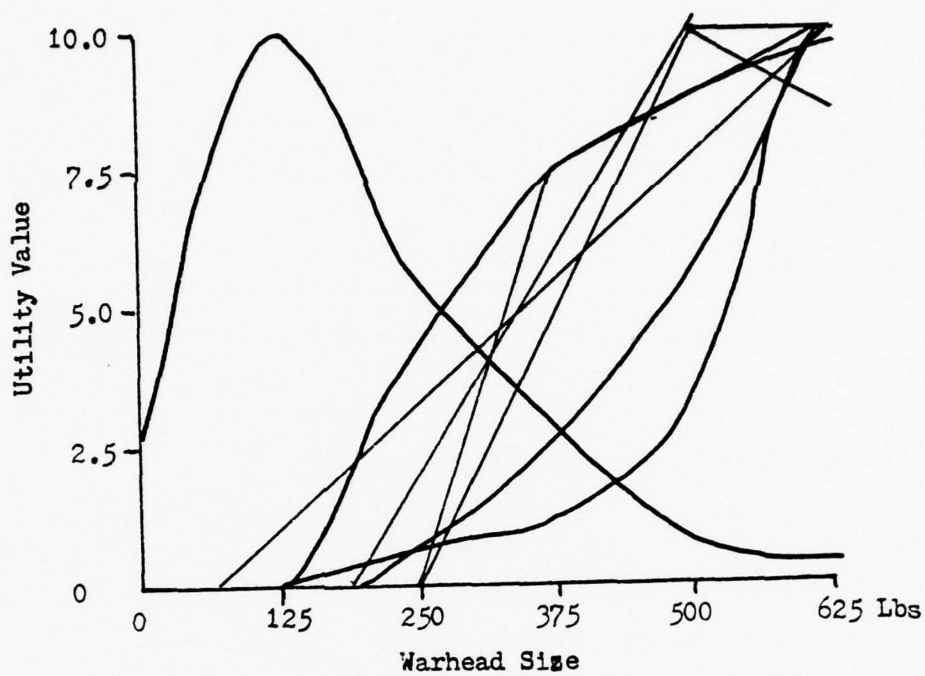
MISSILE SPEED (SCENARIO #1)



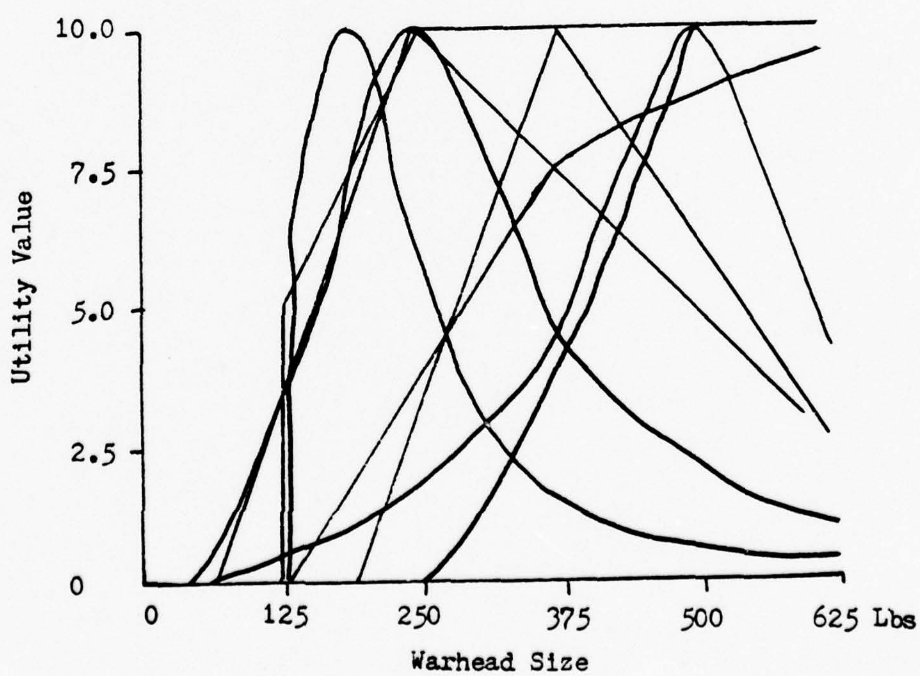
MISSILE SPEED (SCENARIO #2)



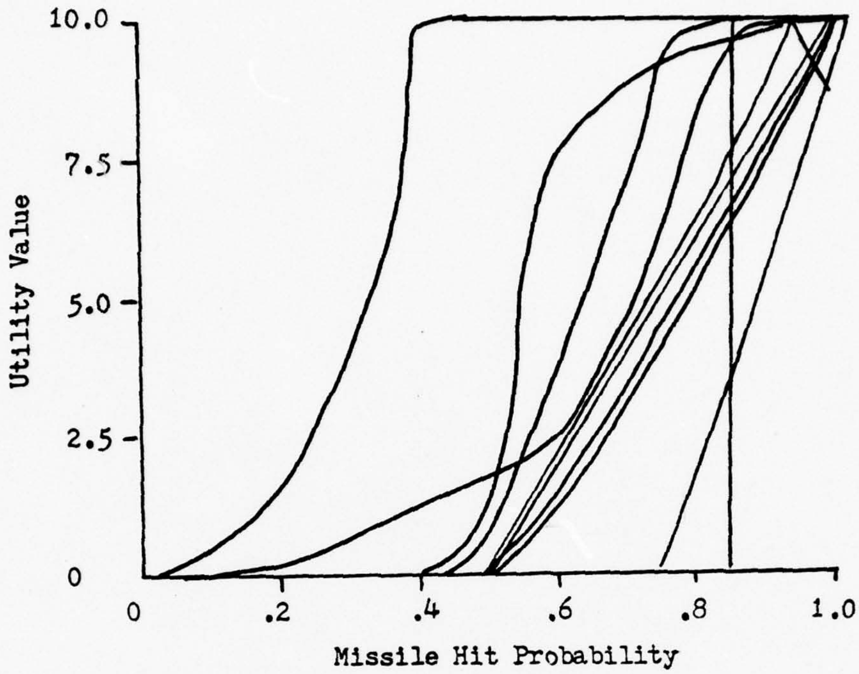
WARHEAD SIZE (SCENARIO #1)



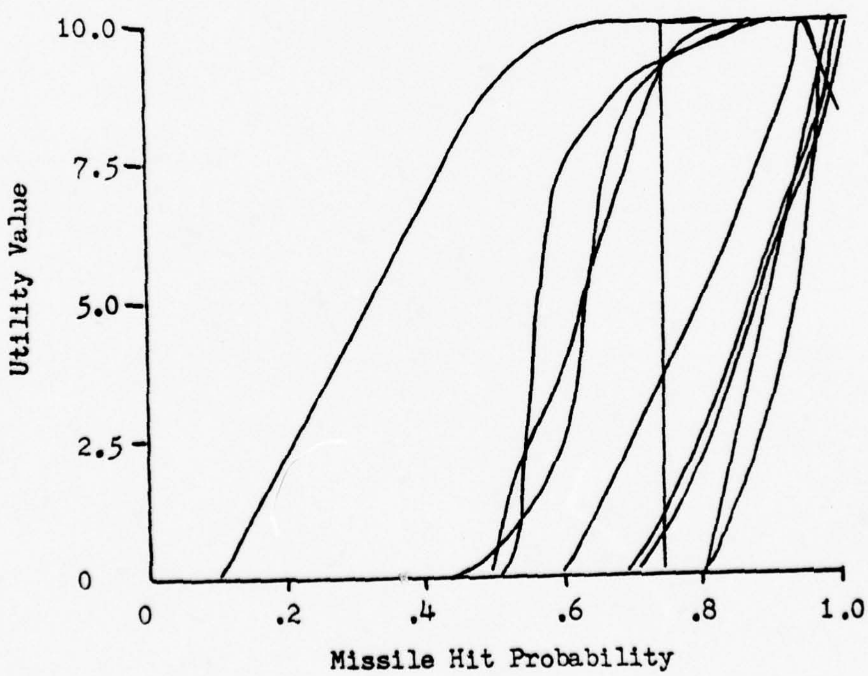
WARHEAD SIZE (SCENARIO #2)



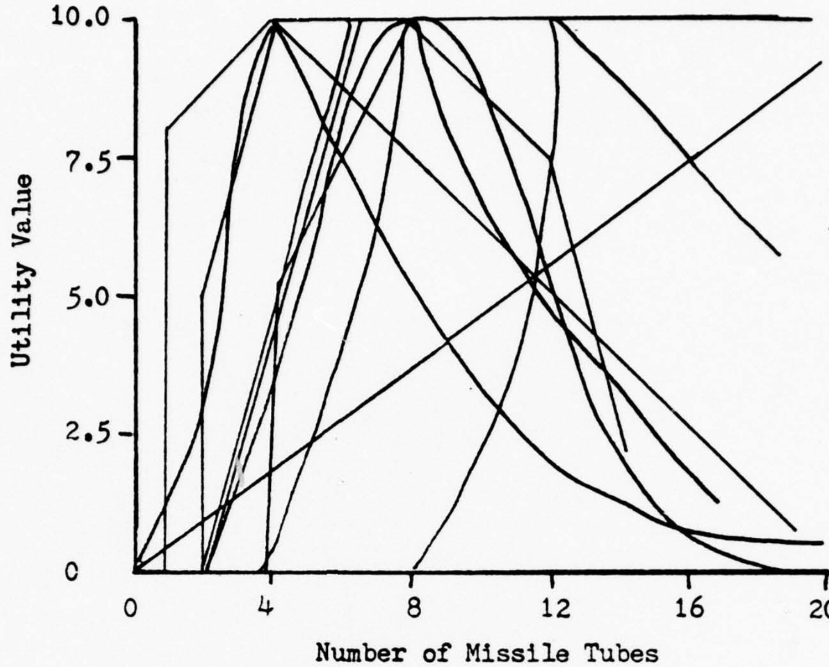
MISSILE HIT PROBABILITY (SCENARIO #1)



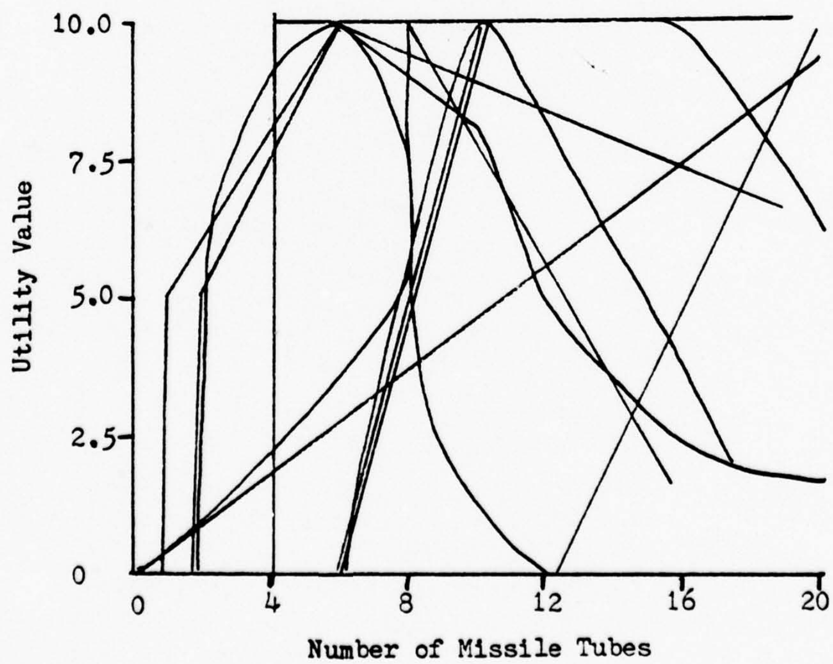
MISSILE HIT PROBABILITY (SCENARIO #2)



NUMBER OF MISSILE TUBES (SCENARIO #1)



NUMBER OF MISSILE TUBES (SCENARIO #2)



MISSILE GUIDANCE SYSTEMS (SCENARIO #1)

	Judges' Scores #1	#2	#3	#4	#5	#6	#7	#8	#9	Average Score
Inertial with Active Radar Terminal Guidance	5		4	5	10	7			9	6.7
Autopilot with Active Radar Terminal Guidance	6		10	10	8	9			10	8.8
Command with Active Radar Terminal Guidance	5		5	9	7	10			3	6.5
Command with Semi-Active Radar Terminal Guidance	5		5	4	5	6			2	4.5
Beam Rider	2		6	0	0	3	3	3	0	1.8
Active Radar	3		8	8	10	8	3	3	8	6.4
Anti-Radiation Homing	6		3	6	7	4	5	5	6	5.3
Wire Guided	1		0	2	8	5	0	0	0	3.2

MISSILE GUIDANCE SYSTEMS (SCENARIO #2)

	#1	#2	#3	#4	#5	#6	#7	#8	#9	Average Score
Inertial with Active Radar Terminal Guidance	7		9	0	10	6			9	6.8
Autopilot with Active Radar Terminal Guidance	8		6	8	8	8			10	8.0
Command with Active Radar Terminal Guidance	3		7	10	7	9			3	6.5
Command with Semi-Active Radar Terminal Guidance	6		9	2	5	7			2	5.2
Beam Rider	1		4	1	0	3	2	2	0	1.6
Active Radar	5		9	5	10	5	2	2	8	5.8
Anti-Radiation Homing	8		1	3	7	10	6	6	6	5.9
Wire Guided	0		0	6	4	4	0	0	0	1.8

HOME-ON-JAM CAPABILITY (SCENARIO #2)

	Judges' Scores									Average
	#1	#2	#3	#4	#5	#6	#7	#8	#9	Score
Scenario #1	5		1	9	10	4			10	6.5
Scenario #2	10		4	7	10	10			10	8.5

FUZING CONFIGURATIONS (SCENARIO #1)

	Judges' Scores									Average
	#1	#2	#3	#4	#5	#6	#7	#8	#9	Score
Contact Fuze	5		10	7		8	9	9	6	7.7
Contact with Delay	8		5	10		9	10	10	10	8.9
Proximity Fuze	4		6	5		10	5	5	4	5.6

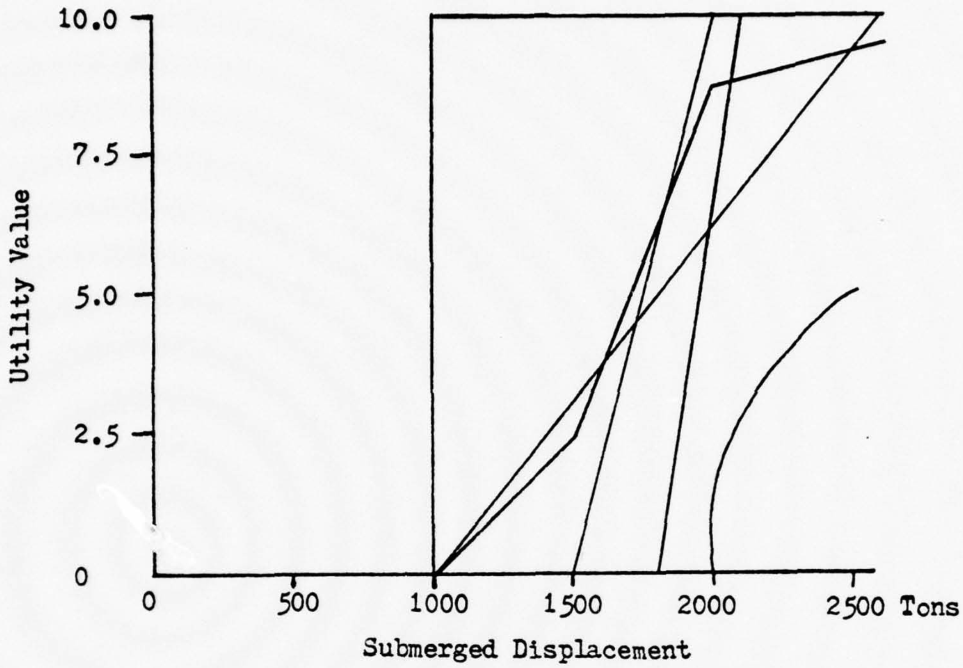
FUZING CONFIGURATIONS (SCENARIO #2)

	#1	#2	#3	#4	#5	#6	#7	#8	#9	Average Score
Contact Fuze	6		6	6		9	9	9	5	7.1
Contact with Delay	8		8	0		10	5	5	8	6.3
Proximity Fuze	10		10	10		8	10	10	10	9.7

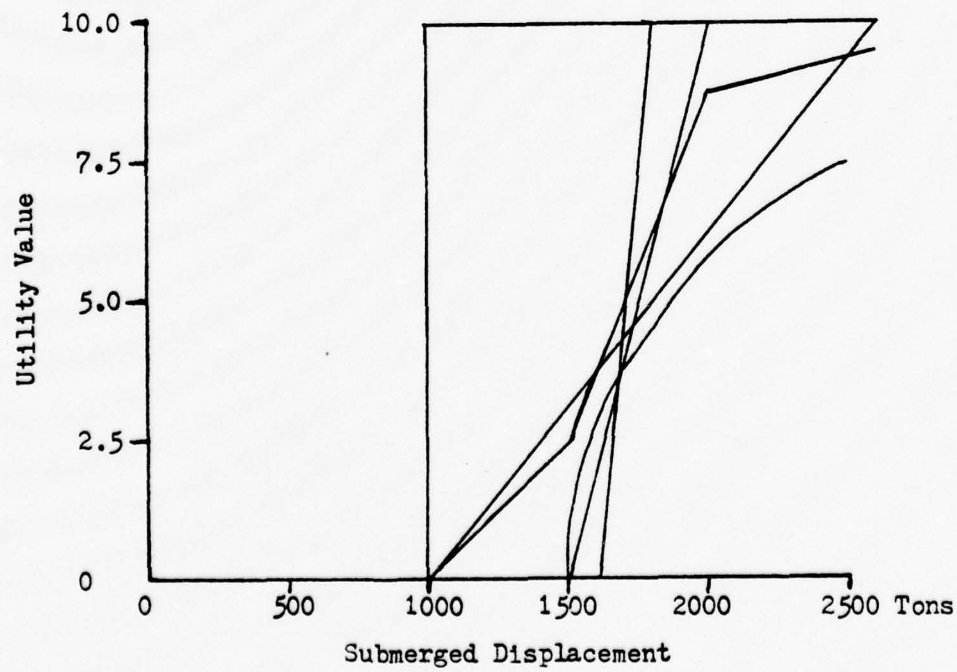
APPENDIX E

TORPEDO-FIRING DIESEL SUBMARINE QUESTIONNAIRE RESULTS

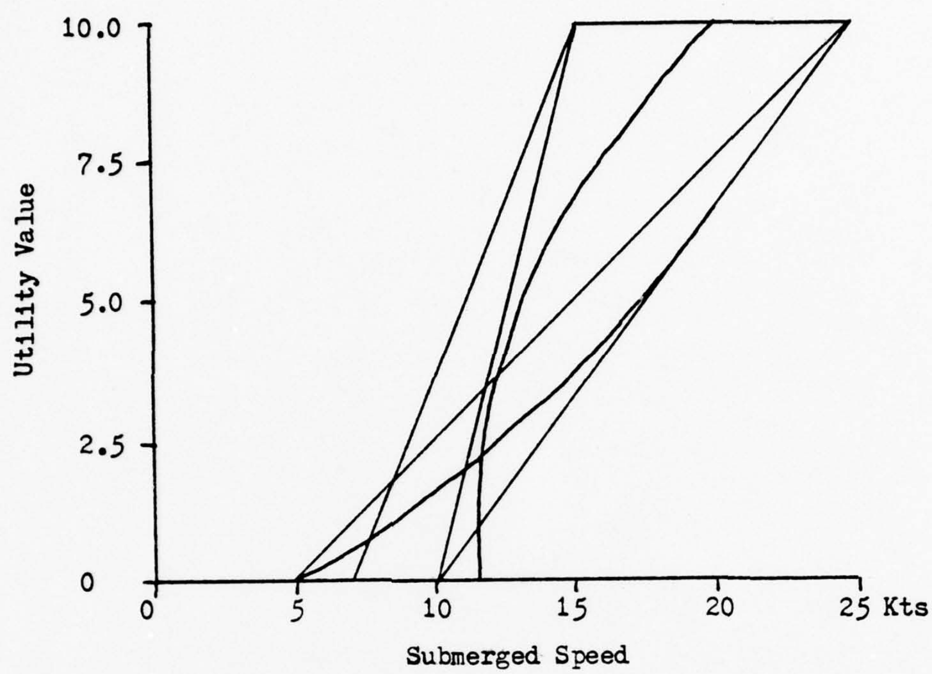
SUBMERGED DISPLACEMENT (SCENARIO #1)



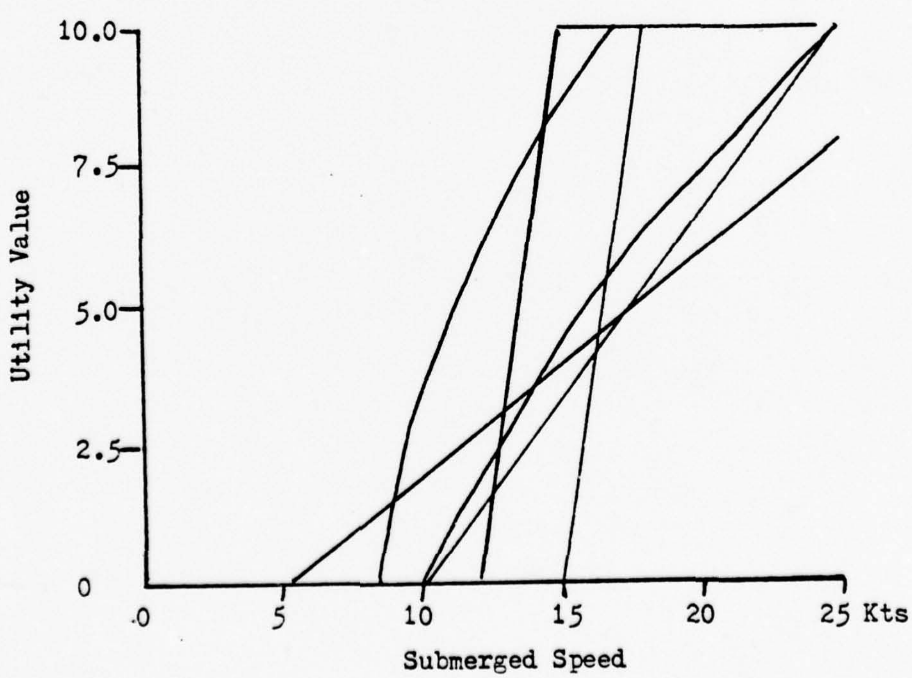
SUBMERGED DISPLACEMENT (SCENARIO #2)



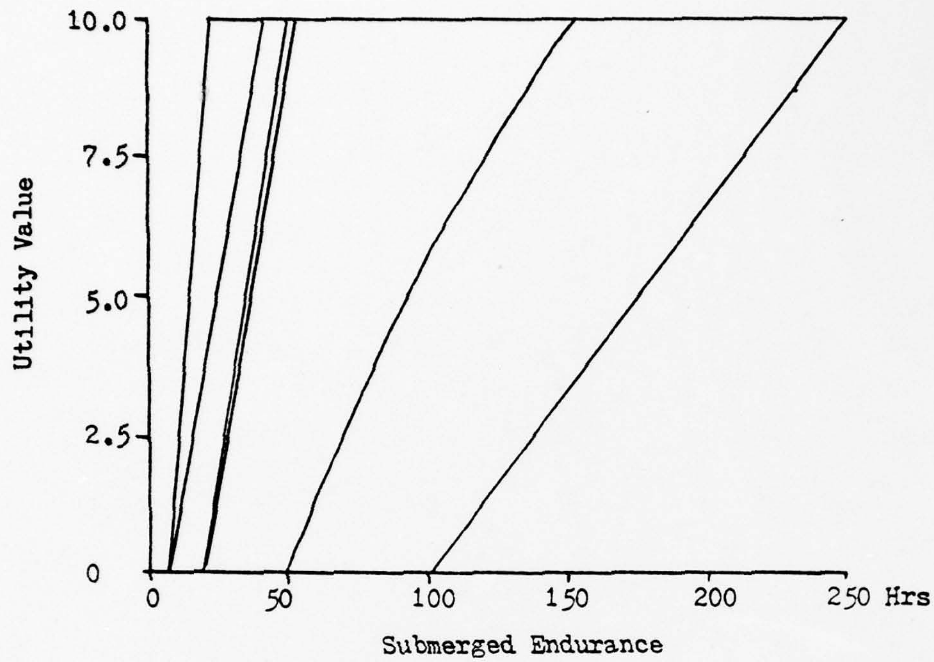
SUBMERGED SPEED (SCENARIO #1)



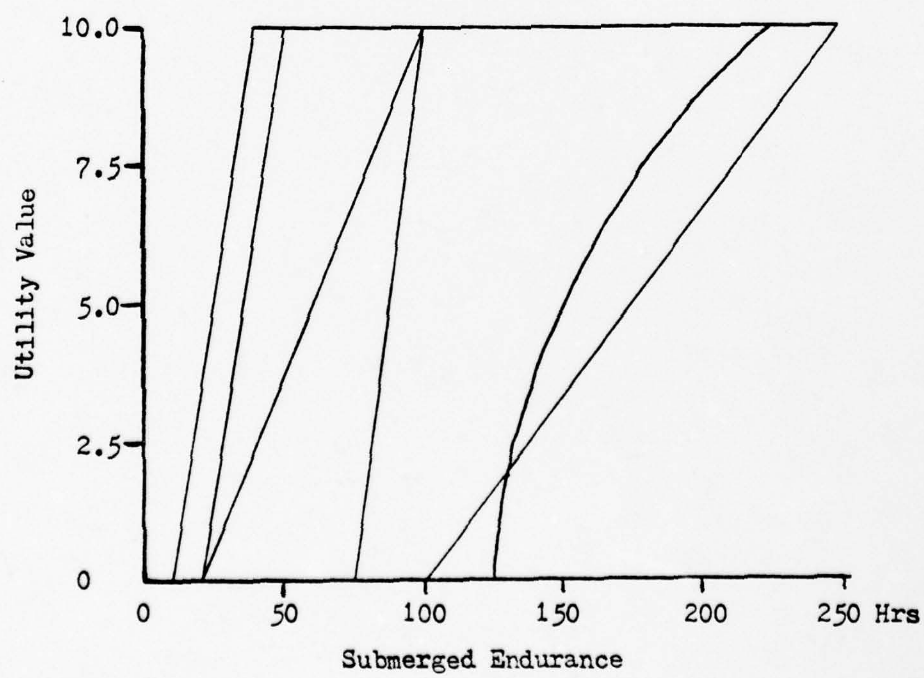
SUBMERGED SPEED (SCENARIO #2)



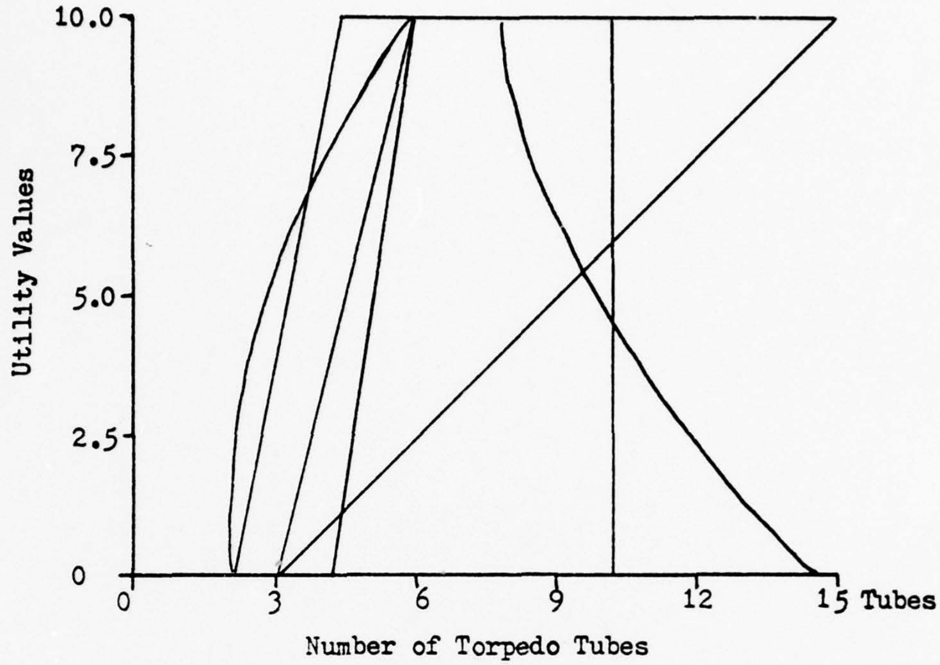
SUBMERGED ENDURANCE (SCENARIO #1)



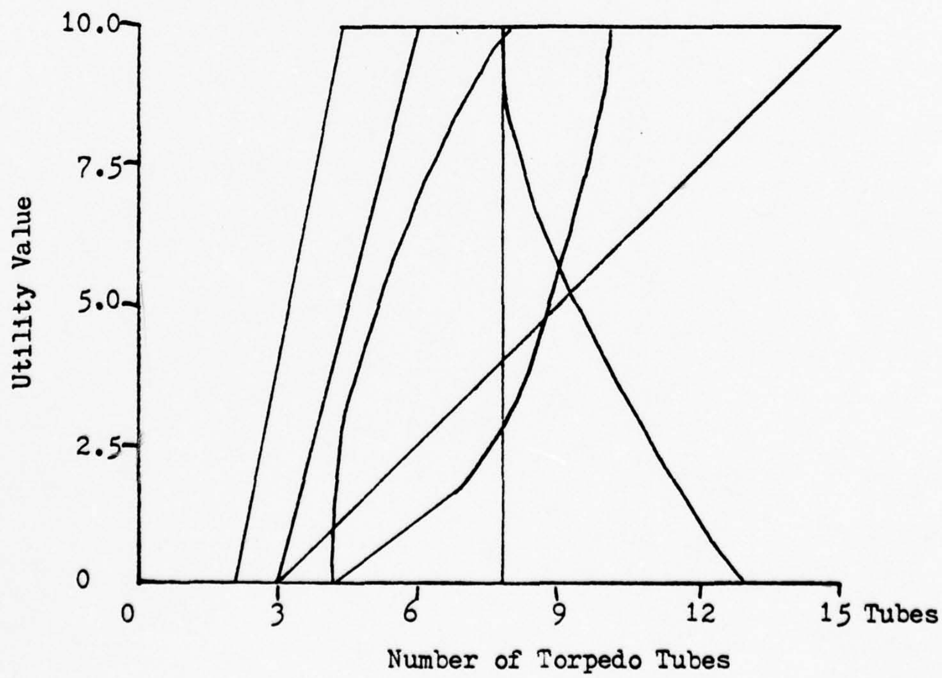
SUBMERGED ENDURANCE (SCENARIO #2)



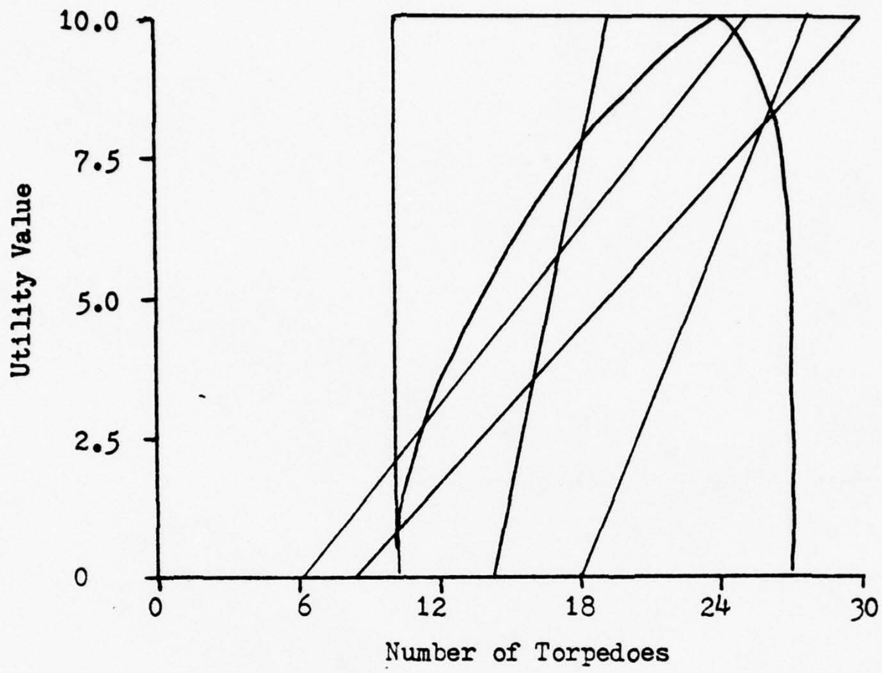
NUMBER OF TORPEDO TUBES (SCENARIO #1)



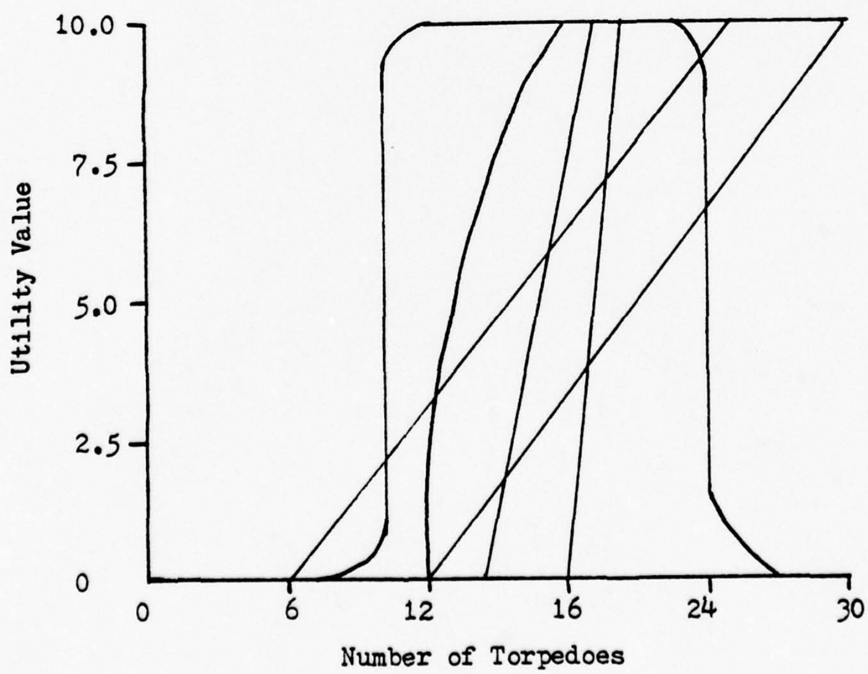
NUMBER OF TORPEDO TUBES (SCENARIO #2)



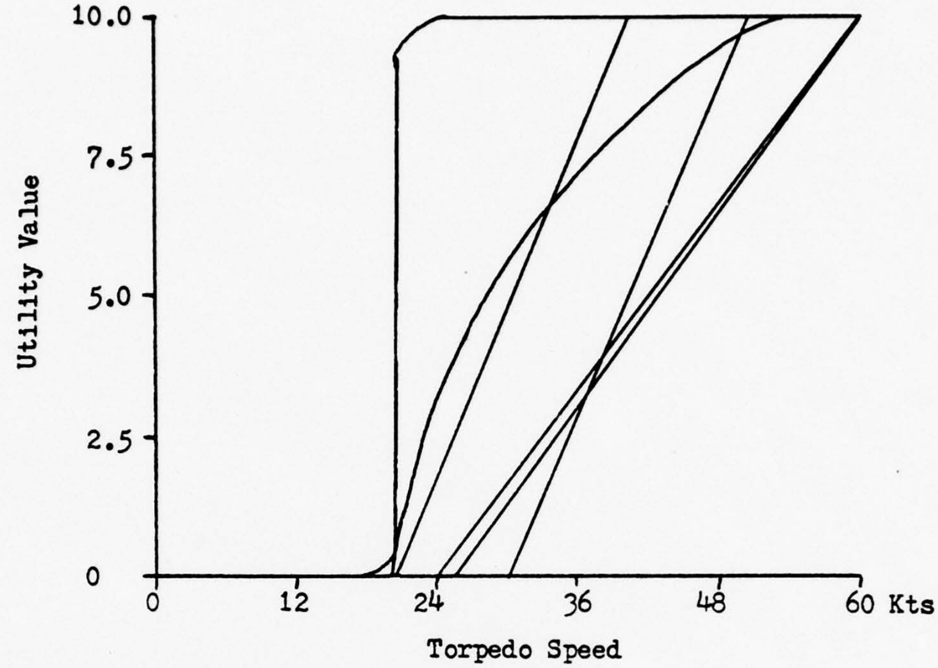
NUMBER OF TORPEDOES (SCENARIO #1)



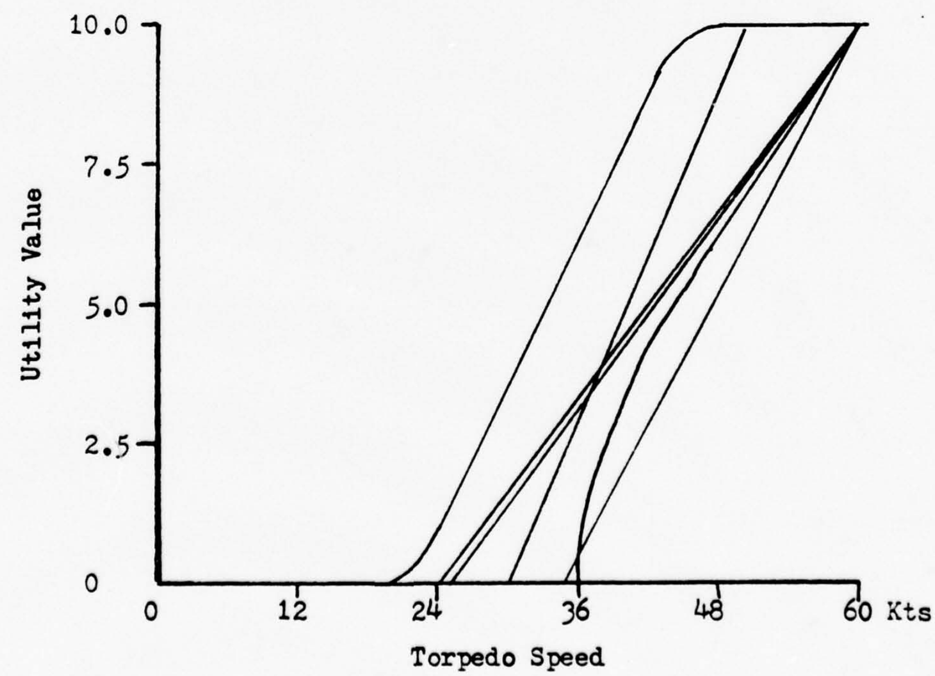
NUMBER OF TORPEDOES (SCENARIO #2)



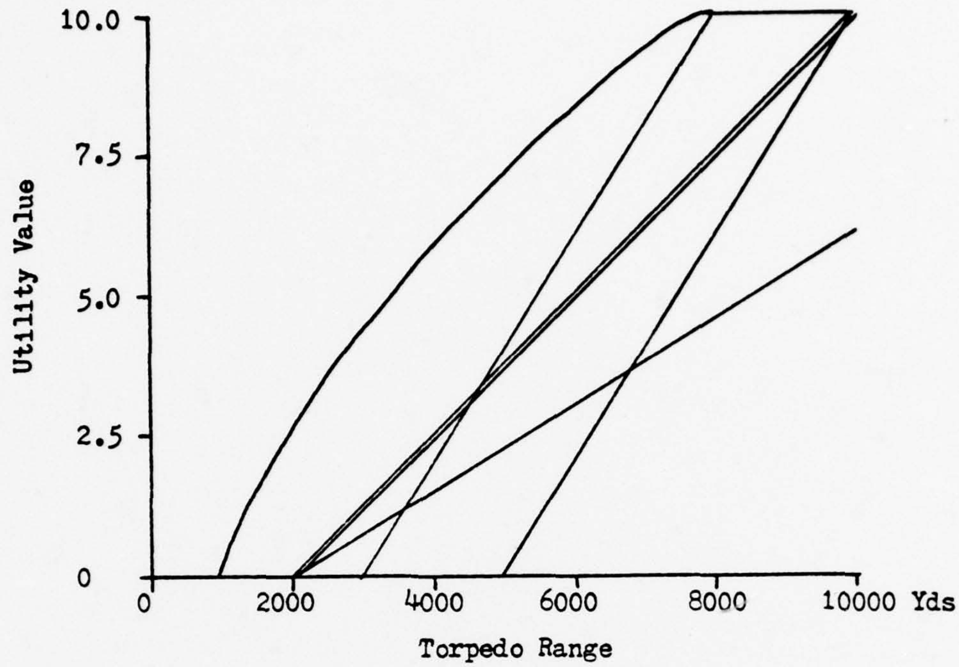
TORPEDO SPEED (SCENARIO #1)



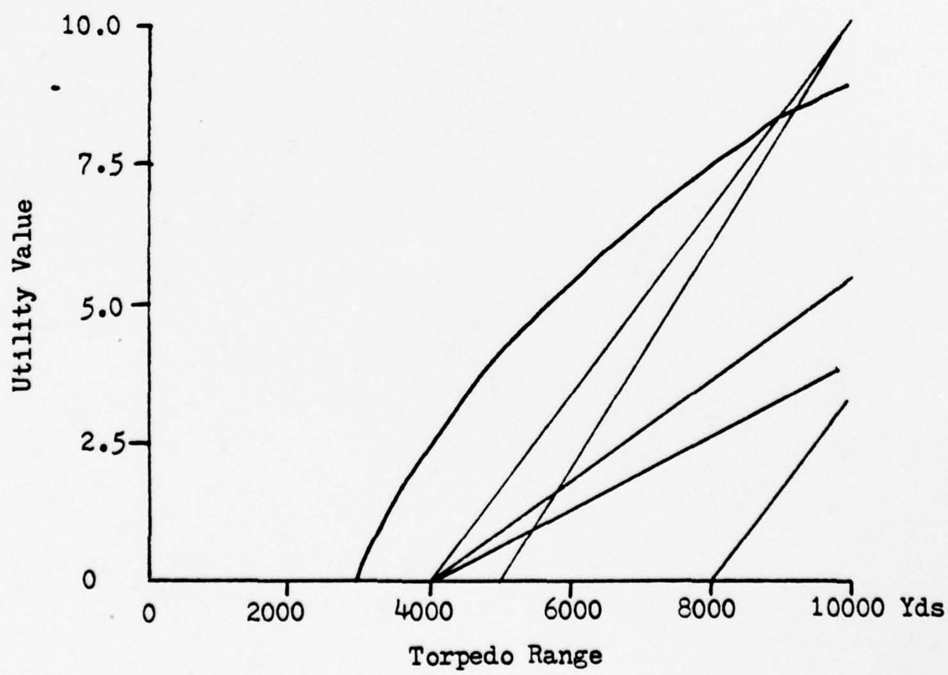
TORPEDO SPEED (SCENARIO #2)



TORPEDO RANGE (SCENARIO #1)



TORPEDO RANGE (SCENARIO #2)



TORPEDO GUIDANCE SYSTEMS (SCENARIO #1)

	Judges' Scores #1	#2	#3	#4	#5	#6	Average Score
Anti-Surface/Non-Electric "Steam-fish"	8	6	0	8	8	3	5.5
Acoustic	9	8	9	9	9	7	8.5
Wire-Guided	10	10	10	10	10	5	9.2

TORPEDO GUIDANCE SYSTEMS (SCENARIO #2)

	#1	#2	#3	#4	#5	#6	Average Score
Anti-Surface/Non-Electric "Steam-fish"	4	0	0	2	3	2	2.0
Acoustic	9	4	9	8	10	7	7.8
Wire-Guided	10	10	10	10	8	9	9.5

ACQUISITION TECHNIQUES (SCENARIO #1)

	Judges' Scores #1	#2	#3	#4	#5	#6	Average Score
Visual	5	6	10	10	7	9	7.8
Active Sonar	0	0	0	2	0	7	1.5
Passive Sonar	9	7	10	10	9	5	8.3
Active and Passive Sonars	9	7	10	10	2	6	7.3

ACQUISITION TECHNIQUES (SCENARIO #2)

	#1	#2	#3	#4	#5	#6	Average Score
Visual	3	3	10	10	7	8	6.8
Active Sonar	0	0	0	0	0	2	0.3
Passive Sonar	8	10	10	10	9	7	9.0
Active and Passive Sonars	8	10	10	5	1	3	6.2

ESM CAPABILITY

	Judges' Scores #1	#2	#3	#4	#5	#6	Average Score
Scenario #1	6	9	3	4	9	4	5.8
Scenario #2	9	6	4	10	9	7	7.5

(SLAM) CAPABILITY

	Judges' Scores #1	#2	#3	#4	#5	#6	Average Score
Scenario #1	10	8	5	0	3	1	4.5
Scenario #2	8	10	5	5	7	8	7.2

APPENDIX F

PERSONNEL-RELATED QUESTIONNAIRE

NAVAL POSTGRADUATE SCHOOL
Monterey, California

From: Curricular Officer, Naval Intelligence Curriculum (Code-38)
To:

Subj: Sea Denial Capabilities Questionnaire

Encl: (1) Questionnaire instructions.
(2) Country list #1.
(3) Country list #2.
(4) Country list #3.

1. Enclosures 1-4 represent one part of a student research project currently underway at the Naval Postgraduate School. Results of this questionnaire will be incorporated into a thesis being prepared by LT Lowell E. Jacoby as a degree requirement in the Naval Intelligence Curriculum.

2. Your participation in this research effort would be greatly appreciated.

T.H. Barr

T.H. BARR

Enclosure (1)

SEA DENIAL CAPABILITIES MEASUREMENT

Questionnaire Instructions

This questionnaire is part of a student research project being conducted by LT Lowell E. Jacoby at the Naval Postgraduate School. The research is attempting to evaluate the sea denial capabilities of various nations. Countries selected for study have or will receive anti-ship missile-equipped surface ships and/or torpedo-firing diesel submarines.

Based on your expertise, you are asked to judge the various nations' capabilities to successfully operate these weapons platforms in an open ocean sea denial mission. Criteria for this evaluation might include (but not necessarily be limited to): a proven ability to perform this mission, the technology/training needed to maintain these weapons systems, and the ability to man these platforms with crews adequately trained to perform the mission.

Specifically, you are asked to divide 100 points between the two countries in each of the pairs contained in Enclosures 2, 3, and 4 in such a way as to reflect their relative capabilities to perform the open ocean sea denial mission with an anti-ship missile-equipped surface combatant and/or a torpedo-firing diesel submarine. For example, if two judges made the following point divisions it would indicate that Judge #1 feels that France is four times more capable than Albania, while Judge #2 feels that the two countries possess equal sea denial capabilities.

Judge #1		Judge #2	
Albania	20	Albania	50
France	80	France	50

Again, let me emphasize that the questionnaire seeks to elicit a personal judgement based on your expertise.

Thank you very much for your participation.

Enclosure (1)

COUNTRY LIST #1

(Middle East/Indian Ocean/Africa)

Egypt Iran	Iran Pakistan	Iraq Tunisia
Egypt Iraq	Iran India	Iraq Ivory Coast
Egypt Israel	Iran Algeria	Iraq Syria
Egypt Saudi Arabia	Iran Libya	Israel Saudi Arabia
Egypt Pakistan	Iran Morocco	Israel Pakistan
Egypt India	Iran Tunisia	Israel India
Egypt Algeria	Iran Ivory Coast	Israel Algeria
Egypt Libya	Iran Syria	Israel Libya
Egypt Morocco	Iraq Israel	Israel Morocco
Egypt Tunisia	Iraq Saudi Arabia	Israel Tunisia
Egypt Ivory Coast	Iraq Pakistan	Israel Ivory Coast
Egypt Syria	Iraq India	Israel Syria
Iran Iraq	Iraq Algeria	Saudi Arabia Pakistan
Iran Israel	Iraq Libya	Saudi Arabia India
Iran Saudi Arabia	Iraq Morocco	Saudi Arabia Algeria

COUNTRY LIST #1 (Continued)

Saudi Arabia Libya	___ ___	Pakistan Syria	___ ___	Algeria Syria	___ ___
Saudi Arabia Morocco	___ ___	India Algeria	___ ___	Libya Morocco	___ ___
Saudi Arabia Tunisia	___ ___	India Libya	___ ___	Libya Tunisia	___ ___
Saudi Arabia Ivory Coast	___ ___	India Morocco	___ ___	Libya Ivory Coast	___ ___
Saudi Arabia Syria	___ ___	India Tunisia	___ ___	Libya Syria	___ ___
Pakistan India	___ ___	India Ivory Coast	___ ___	Morocco Tunisia	___ ___
Pakistan Algeria	___ ___	India Syria	___ ___	Morocco Ivory Coast	___ ___
Pakistan Libya	___ ___	Algeria Libya	___ ___	Morocco Syria	___ ___
Pakistan Morocco	___ ___	Algeria Morocco	___ ___	Tunisia Ivory Coast	___ ___
Pakistan Tunisia	___ ___	Algeria Tunisia	___ ___	Tunisia Syria	___ ___
Pakistan Ivory Coast	___ ___	Algeria Ivory Coast	___ ___	Ivory Coast Syria	___ ___

Enclosure (3)

COUNTRY LIST #2

(Indian Ocean/Far East)

India ____ South Africa ____	South Africa ____ Malaysia ____	PRC ____ S. Korea ____
India ____ Brunei ____	South Africa ____ Singapore ____	PRC ____ Malaysia ____
India ____ PRC ____	South Africa ____ Taiwan ____	PRC ____ Singapore ____
India ____ Indonesia ____	South Africa ____ Thailand ____	PRC ____ Taiwan ____
India ____ N. Korea ____	South Africa ____ Vietnam ____	PRC ____ Thailand ____
India ____ S. Korea ____	Brunei ____ PRC ____	PRC ____ Vietnam ____
India ____ Malaysia ____	Brunei ____ Indonesia ____	Indonesia ____ N. Korea ____
India ____ Singapore ____	Brunei ____ N. Korea ____	Indonesia ____ S. Korea ____
India ____ Taiwan ____	Brunei ____ S. Korea ____	Indonesia ____ Malaysia ____
India ____ Thailand ____	Brunei ____ Malaysia ____	Indonesia ____ Singapore ____
India ____ Vietnam ____	Brunei ____ Singapore ____	Indonesia ____ Taiwan ____
South Africa ____ Brunei ____	Brunei ____ Taiwan ____	Indonesia ____ Thailand ____
South Africa ____ PRC ____	Brunei ____ Thailand ____	Indonesia ____ Vietnam ____
South Africa ____ Indonesia ____	Brunei ____ Vietnam ____	N. Korea ____ S. Korea ____
South Africa ____ N. Korea ____	PRC ____ Indonesia ____	N. Korea ____ Malaysia ____
South Africa ____ S. Korea ____	PRC ____ N. Korea ____	N. Korea ____ Singapore ____

Enclosure (3)

COUNTRY LIST #2 (Continued)

N. Korea ____ Taiwan ____	S. Korea ____ Thailand ____	Singapore ____ Taiwan ____
N. Korea ____ Thailand ____	S. Korea ____ Vietnam ____	Singapore ____ Thailand ____
N. Korea ____ Vietnam ____	Malaysia ____ Singapore ____	Singapore ____ Vietnam ____
S. Korea ____ Malaysia ____	Malaysia ____ Taiwan ____	Taiwan ____ Thailand ____
S. Korea ____ Singapore ____	Malaysia ____ Thailand ____	Taiwan ____ Vietnam ____
S. Korea ____ Taiwan ____	Malaysia ____ Vietnam ____	Thailand ____ Vietnam ____

COUNTRY LIST #3

(South America/Central America/Eastern Mediterranean)

Argentina Brazil	___ ___	Brazil Peru	___ ___	Columbia Cuba	___ ___
Argentina Chile	___ ___	Brazil Uruguay	___ ___	Columbia Ecuador	___ ___
Argentina Columbia	___ ___	Brazil Venezuela	___ ___	Columbia Peru	___ ___
Argentina Cuba	___ ___	Brazil Greece	___ ___	Columbia Uruguay	___ ___
Argentina Ecuador	___ ___	Brazil Turkey	___ ___	Columbia Venezuela	___ ___
Argentina Peru	___ ___	Brazil Israel	___ ___	Columbia Greece	___ ___
Argentina Uruguay	___ ___	Chile Columbia	___ ___	Columbia Turkey	___ ___
Argentina Venezuela	___ ___	Chile Cuba	___ ___	Columbia Israel	___ ___
Argentina Greece	___ ___	Chile Ecuador	___ ___	Cuba Ecuador	___ ___
Argentina Turkey	___ ___	Chile Peru	___ ___	Cuba Peru	___ ___
Argentina Israel	___ ___	Chile Uruguay	___ ___	Cuba Uruguay	___ ___
Brazil Chile	___ ___	Chile Venezuela	___ ___	Cuba Venezuela	___ ___
Brazil Columbia	___ ___	Chile Greece	___ ___	Cuba Greece	___ ___
Brazil Cuba	___ ___	Chile Turkey	___ ___	Cuba Turkey	___ ___
Brazil Ecuador	___ ___	Chile Israel	___ ___	Cuba Israel	___ ___

COUNTRY LIST #3 (Continued)

Ecuador ____
Peru ____

Ecuador ____
Uruguay ____

Ecuador ____
Venezuela ____

Ecuador ____
Greece ____

Ecuador ____
Turkey ____

Ecuador ____
Israel ____

Peru ____
Uruguay ____

Peru ____
Venezuela ____

Peru ____
Greece ____

Peru ____
Turkey ____

Peru ____
Israel ____

Uruguay ____
Venezuela ____

Uruguay ____
Greece ____

Uruguay ____
Turkey ____

Uruguay ____
Israel ____

Venezuela ____
Greece ____

Venezuela ____
Turkey ____

Venezuela ____
Israel ____

Greece ____
Turkey ____

Greece ____
Israel ____

Turkey ____
Israel ____

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